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NSW Agriculture

Root knot disease and its control

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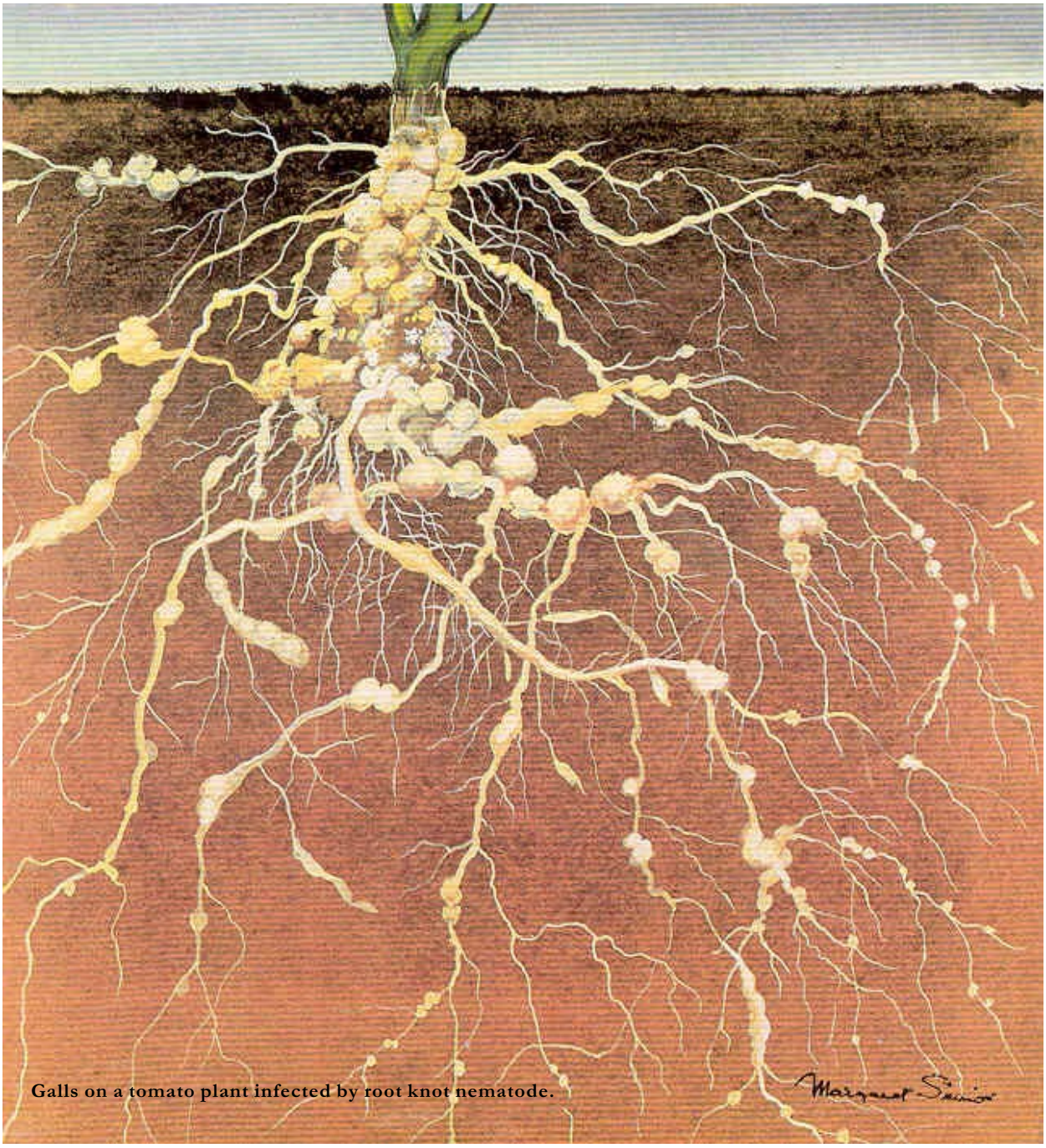


Galls on a tomato plant infected by root knot nematode.

ORDER NO. AB.1

AGDEX 633

THE DISEASE

Root knot disease is prevalent throughout most of New South Wales. A great many broad-leafed plants are susceptible to infection. Grasses are affected less often and show little obvious knotting. In cultivated crops, the disease is important in the growing of tobacco, tomatoes and many other vegetables, stone fruits, vines and cut flowers. In the production of propagating material and nursery stock constant attention is needed to prevent infection.

CAUSE

The disease is caused by microscopic, parasitic, soil-inhabiting nematodes, otherwise known as eelworms, of the genus *Meloidogyne*. These nematodes burrow into the soft tissues of *root* tips and young roots, and cause the nearby root cells to divide and enlarge. Four different species of *Meloidogyne* are common in New South Wales: *M. javanica. M. incognita. M. hapla* and *M. arenaria*.

SYMPTOMS

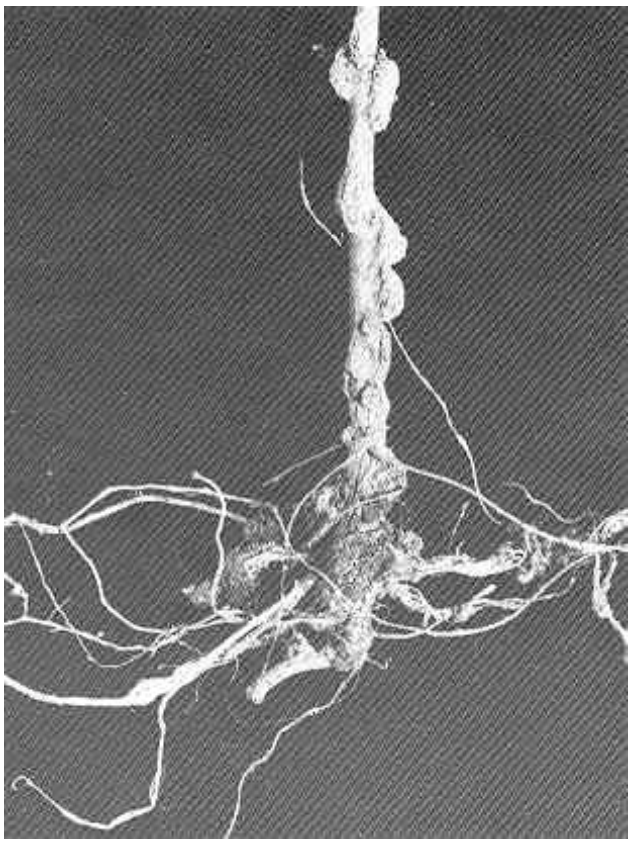
Affected crops may show one or more of the following signs of attack: slow / stunted growth, yellowing of the leaves, wilting of the plant despite adequate soil water content, collapse of individual plants. Severely infected seedlings produce few roots and usually die rapidly. Heavy infection of older plants causes the plants to wilt unexpectedly and die off early.

Swellings, or galls, develop on the roots of infected plants, as the result of nematode-induced expansion of root cells. The galls vary in size from slight thickenings to lumps 5 to 10 cm across. Stems or leaves may be galled but this is rarely seen in plants growing outdoors. Galls caused by *Meloidogyne hapla* are much smaller than those caused by other species.

All root knot galls damage the vascular tissues of roots and thus interfere with the normal movement of water and nutrients through the plant. They also increase the susceptibility of the root system to invasion by disease-causing fungi and bacteria. Galls caused by nematodes

Small galls caused by nematodes on roots of Chinese gooseberry.

Large galls on root of paw paw.



Galls caused by root knot nematode on stem of a bean plant.

Root knot nematode infection produces a small, warty, unatractive potato.

should not be confused with the small nodules on the roots of leguminous plants such as peas, beans, clover and lucerne. These nodules develop as a result of the presence of beneficial nitrogen-fixing bacteria. True root nodules of this type are readily detached and are pink or green inside.

Root knot nematodes cause losses in potato crops by disfiguring the tubers. Infection shows up conspicuously as pimple-like outgrowths on the skin, and the whole surface may become warty and discoloured. If one of the pimple-like outgrowths is cut open, the nematode may be seen using a magnifying glass as a small, glistening body embedded in the tissue.

NEMATODE LIFE-CYCLE

Second stage juveniles of nematodes (larvae) hatch from eggs laid in either the soil or plant tissues. On emergence, the juveniles, thread-like in appearance, actively seek the tips of roots for invasion. When established in the root tissue, the nematodes feed on the plant cells and grow. The infected cells are then stimulated to enlarge and become the feeding sites for the nematodes. As the nematodes mature they moult three times inside the roots. During the final developmental stage, the body of the female changes into a spherical or pear-shape while the male remains long and cylindrical. At this stage, the female is large enough to be seen with a magnifying glass when galled root tissue is broken open. Under climatic conditions favourable for nematode activity, fully developed females may commence egg laying 3 to 4 weeks after entry into root tissue and can produce up to 2000 eggs. The eggs generally hatch in warm moist soils and some eggs can survive for at least a year. In some subtropical regions up to ten generations can be produced per year. However, in the Sydney district and areas with similar cool winters, the nematodes are less active during the winter months compared to summer / warmer months.

INFECTION AND SPREAD

Nematodes are most often introduced into a new paddock or area by planting seedlings, tubers, or young plants that are already infected with root knot. It can also be spread to new areas by running water, cultivation tools and machinery, animals and footwear. Without the help of these distributing agents, spread is only a few centimetres each year within a paddock.

The disease is favoured by warm weather and is most troublesome in sandy soils.

CONTROL

MANAGEMENT STRATEGIES

Sanitation: preventing buildup and spread

As far as possible, grow your own seedlings and other propagating material in nematode free soil, and test your soil for nematodes before planting in main fields. If your field soil has nematodes, take preventive measures (e.g. soil sterilisation, chemical application, cultivation of non-host crops etc.) before planting any materials.

If you have obtained rooted plants, tubers, or other materials from a nursery or other outside source, you should examine them carefully for signs of root knot nematode infection (e.g. 'galls'). Discard or refuse to accept delivery of infected plants or plant materials.

Before preparing the soil, thoroughly clean any implements that have been used in contaminated areas.

Burn diseased plants

Do not throw the refuse on to compost or manure heaps. Before feeding affected potatoes to livestock, boil them to destroy nematodes.

Practise crop rotation

Do not plant susceptible crops repeatedly in the same areas. Alternate with crops tolerant of root knot nematodes, for example maize, onions, cabbages and cauliflowers. Cultivate a green manuring crop, such as sorghum in summer and oats or barley in winter. Incorporate the green manures into the soil and ensure that the organic matters have decomposed prior to planting.

Summer fallow

Summer fallowing, in which all vegetation is kept off the infested area, is a cheap and effective way to reduce nematode numbers. Till the soil after each period of rain. This will not stop nematode eggs from hatching but, without food plants, the young worms will die.

Solarisation

Solarisation involves covering raised and moist beds with clear plastic for 2–4 months during the hottest months of the year. The increased soil temperature helps to kill many soil borne pests and pathogens including root knot nematode. Nematodes in these moist beds will hatch out from eggs, move around for roots and will die of starvation.

Organic amendments

Beneficial microorganisms are in high numbers in soil amended with different organic matters. Some beneficial fungi and bacteria are parasites of nematode eggs and also prey on nematodes. The parasitised eggs do not hatch and thus populations are reduced. The predatory nematodes that prey on other nematodes are also high in organic amended soil. Thus organic amendments enhance biological suppression of parasitic nematodes in soil. The organic matters mostly used to control root knot nematodes are poultry manure, pigeon litter, sawdust and various crop residues.

SOIL STERILISATION AND FUMIGATION

If you have to use nematode-infested soil, treat it to reduce or eliminate the nematode population. From the several methods available, select one that suits your need, bearing in mind the cost of treatment in relation to the crop value.

Low-temperature steaming

In recent years it has been recognised that high-temperature steaming of soil (82^0C and above) destroys soil nutrients and breaks down soil structure, as well as killing the soil microorganisms. Since both useful microorganisms are removed from the soil as well as disease- causing ones, there is little competition for any parasitic fungi that invade the soil after steaming. Therefore, if the fungi that cause damping-off type diseases are introduced into soil sterilised by high-temperature steaming, losses of seedlings will be much greater than in unsterilised soil. To overcome these problems methods of low-temperature steaming were developed. The soil is treated for 30 minutes at 60^0C. This will eradicate nematodes and other harmful organisms without killing too many of the beneficial organisms in the soil.

Steam is mixed with regulated amounts of air, by either a venturi steam injector, or by blowing steam into an air pipe. Very efficient equipment is available commercially. Aerated

steam passes into a chamber in the base of a soil treatment bin. The soil rests on a mesh screen above this chamber. The top of the box is covered with sacking or a tarpaulin.

Plastic pots are also safely and efficiently sterilised by this method. See Agfact AB.6 *Soil Treatment in the Nursery* for further information on this topic.

Chemical fumigation

All fumigants are harmful if they contact the skin or if the vapours are inhaled. Follow the safety directions on the label.

A number of fumigants suitable for sterilising potting and seedbed soil are on the market (see list). These range from products that are gaseous at room temperatures and must be applied from gas cylinders under gas-tight conditions, to liquids that can be mixed with water and watered on in solution. All are unspecific, that is, they act not only against nematodes but also against most other soil borne pest and disease organisms.

Note that certain crops are damaged by traces of bromine in the soil. Therefore fumigants containing bromine should not be used where these crops are to be grown (the list shows which fumigants contain bromine). Crops sensitive to bromine are celery, garlic, onion, carnation, gladiolus, lily of the valley and snapdragon. If a fumigant containing bromine has been used where these crops are to be grown, any bromine traces can be removed from the soil by leaching. The recommended practice is to apply an irrigation of 120 to 200 mm after fumigation and aeration are completed and, if the soil is heavy, to follow this with a second irrigation of 80 to 200 mm 3 to 4 days later.

Soil fumigation can cause the release of large amounts of available nitrogen, particularly the readily absorbed ammonium form. For this reason, you should use nitrate rather than the ammonium form of nitrogen fertilisers and apply them as a top dressing after planting, not as a basic dressing before planting.

Sterilising glasshouse soil

Where crops such as tomatoes are grown in the same glasshouse each year, soil sterilisation is essential, not only to control nematodes, but also to control parasitic fungi, insects and weeds. The high returns from glasshouse crops make it worthwhile to use steam sterilisation or a chemical, which combines fumigant action against all four pests.

Steam heat treatment. Steam treatment at 60°C for 30 minutes will kill all nematodes, soil insects, and most fungi and bacteria that cause plant diseases. At 82°C it will also kill almost all weed seeds. Steam may be applied through fixed steam lines or movable hollow-spiked harrows.

Sterilising with fumigants. Glasshouse soils are generally most economically treated with products that are mixtures of fumigants. These products are effective against nematodes and fungi. This is particularly important with tomatoes, in which you must control the *Fusarium* and *Verticillium* wilt fungi as well as root knot nematodes.

The bromine present in some fumigants may damage certain crops. See the section on fumigation of seedbed or potting soil for more details and note the information given there on the use of nitrogen fertilisers in conjunction with fumigation.

If manure or compost is to be applied this should be done before fumigation, to ensure that the added material will also be treated. As stated previously, fumigation in this situation can result in the release of large amounts of available nitrogen and cause excessive vegetative growth. For this reason manuring should be done well before fumigation. Allow several extra weeks between fumigation and planting.

Before treatment, prepare the soil for planting the crop. Break up any clods and lumps, and make sure all crop residues have decomposed. Allow 2 weeks between soil treatment and planting.

Field treatment: large areas

Preplanting fumigation. Note that soil fumigants are toxic to plants, and thus can only be applied prior to planting.

Soil preparation – Before fumigation, prepare the soil in advance of seeding or planting. See there are no clods, lumps and undecomposed crop residues, and have the soil moderately loose. Remove any remaining roots of the preceding crop or allow them time to decay. If manure or compost is needed, mix it with the

soil before fumigation. Results are best when the soil is fairly moist and the temperature above 16°C.

Methods of application. The choice of fumigant for large areas is restricted by financial considerations. The cheaper fumigants usually only control nematodes, not other pests. These fumigants are applied at a depth of 15 to 20 cm from fumigation equipment mounted on a tined or chisel point cultivator drawn by a tractor. Fumigant is fed from a container through a metering device to tubing, which delivers it to outlets behind the tines. Fumigants with low vapour pressure and dispersing ability (e.g. Metham sodium) can be applied with spray nozzles. Fumigant may be fed by gravity flow. Details of the construction of a gravity flow fumigation machine are given later in this Agfact. In more efficient equipment, fumigant is fed under pressure by means of a power take-off or a pump driven by land wheel, or by attaching a gas cylinder. If you are not familiar with the application methods, ask your supplier for application details.

Read the container label very carefully for full directions on how much fumigant to use per hectare and for full safety directions.

Soil surface sealing. A float or light roller should be drawn behind the fumigator to close the furrows and compact the surface soil. If possible, irrigate the soil after treatment to further seal the surface against escape of fumigant. It is necessary to water frequently and lightly for the first 3–4 days. The plastic sheeting can also be used for surface sealing to avoid any escape of fumigant. The most widely used plastic sheeting is linear low-density polyethylene (LDPE).

After I to 2 weeks, plough the area to release any remaining fumigant. It is usual to allow 3 weeks between fumigation and planting.

Sensitivity of crops to fumigant injury. As has been mentioned before, some plants are sensitive to traces of bromine in the soil. Since some field fumigants also contain bromine, do not use them on land where celery or other sensitive crops are to be grown. The toxic effect can persist for up to 3 years after application. See the section on fumigation of seedbed or potting soils for further details.

Treatment with non-fumigant nematicides. Non-fumigant nematicides act quite differently to fumigant nematicides. They dissolve in water and move through the soil in solution rather than as a gas. For this reason, their action is not so dependent on the soil temperature at the time they are applied. Also, when applying non-fumigant nematicides soil tilth and moisture are not as critical as they are for fumigant nematicides. As non-fumigant nematicides do not damage plants at rates normally used for nematode control, they can be applied at any time from one week before planting up to the time of planting.

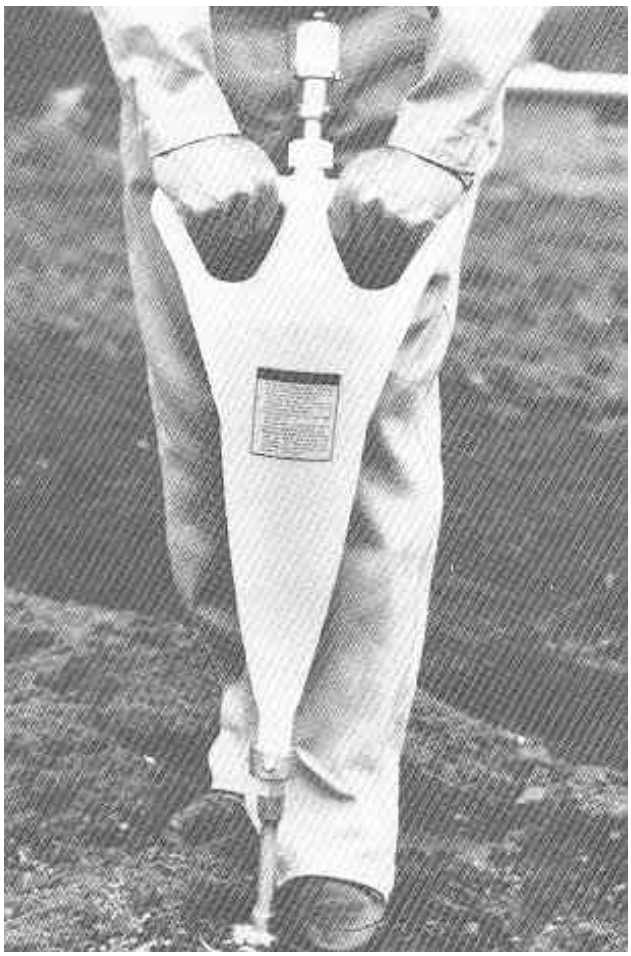
Several non-fumigant nematicides are currently registered in New South Wales. These, and the crops on which they may be used, are listed at the end of this Agfact. Two formulations, granular or emulsifiable liquid concentrate, are available for use against root knot nematodes. Granular formulations are safer to use since they contain 10 per cent or less active ingredient, but they are more expensive than the emulsifiable concentrate. Granules may be easier to apply because they can be broadcast by means of a fertiliser spreader and then cultivated in by using a rotary hoe. The liquid formulation can be applied through drip or trickle irrigation. It has an advantage in that it can be applied mixed with herbicides depending on the compatability of the chemicals.

Safety precautions and detailed instructions for the use of these nematicides are set out on the container labels. Read the label carefully and strictly follow instructions.

Field treatment: smaller areas

Preplanting fumigation. Mark out the area to be fumigated with a series of parallel lines, 30 cm apart, then with another series of lines 30 cm apart at right angles to the first series. The fumigant injection points are at the crossing of these lines in alternate rows, and midway between the points of intersection in the remaining rows. This gives a 'staggered' effect, which makes it easier to cover the whole area to be treated.

Inject 2 mL of fumigant into each hole by means of a soil injector set to inject at a depth of 15 cm. If an injector is not available, holes can be made with a pointed stick, and fumigant poured into them through a funnel.



Hand injector for preplant fumigation of small areas.

Immediately after treatment, seal each hole by tramping with the heel, making the soil as flat and smooth as possible. Small areas can be smoothed over with a hand rake. Moist soils will benefit from the use of a roller.

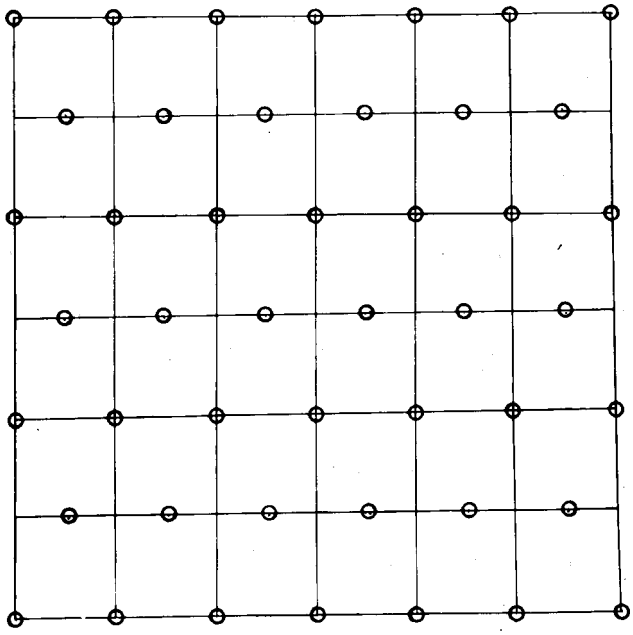
Fumigation will be improved if, immediately after raking, the soil is sprinkled with water, just to the point where it no longer soaks in readily. After 2 weeks, fork the soil over and leave one more week before planting.

Water-on type fumigants are convenient for treating areas such as strawberry beds and nurseries and for row treatment for vegetables.

Remember you must wear protective clothing and other safety equipment when handling fumigants. Read the label for instruction details.

Preplanting fumigation of soil for trees and shrubs. A circular area from I to 2 m in diameter, intended as a planting site, can be fumigated in a manner similar to that set out above for small areas of soil.

As fruit trees, particularly peach, are susceptible to root knot infection, it is important



Recommended staggered arrangement of injection holes.

that the soil be free of root knot nematode. Note that fumigants should be used only as a preplanting treatment and are highly toxic to established plants.

Treatment of established plants. Non-fumigant nematicides may be applied to the soil around plants of certain species (see list). Always check the label directions to be sure you are using the nematicide correctly.

GRAVITY FLOW FUMIGATION MACHINE

All that is needed to construct the machine is a container or drum that can be made airtight, and a number of plumbers' stock fittings.

List of parts

(1) 1 only 19 mm brass socket.

(2) 1 only 19 mm low-pressure stop tap, male thread.

(3) 1 only 19 mm brass tee-piece,

(4) 1 only 19mm brass plug.

(5) 40 cm piece screwing copper pipe, threaded one end.

(6) 2 only 13 mm gas or 19 mm copper flowline tee fittings.

(7) I only 13 mm gas or 19 mm copper flowline elbow.

(8) 3 only 13 mm brass plugs.

(9) 90 cm of 8 mm copper tube; 15 cm of 13 mm copper tube.

(10) Approximately 3 m of 6 mm plastic tubing.

Construction details

First the drum must be made to stand rigidly on the tool bar of a tractor. Drill two 13 mm holes in each side of brass socket (1), and into each of these holes weld one 5 cm piece of 13 mm copper tube.

Drill a 13 mm hole in the side of the drum, near the top, and into this weld one 5 cm piece of 13 mm copper tube.

Drill a 19 mm hole into the bottom of the drum, and over this hole weld brass socket (1). Into this socket screw stop tap (2) and into the stop tap screw brass tee (3). Into the other end of the tee, screw the brass plug (4).

Weld the two flowlines (6) and flowing elbow (7) into line, leaving 13 mm gas outlets all in one line.

On to one end of these fittings, weld 19 mm screwing copper pipe (5). The threaded end of this pipe is then screwed into the side outlet of the 19 mm tee piece (3).

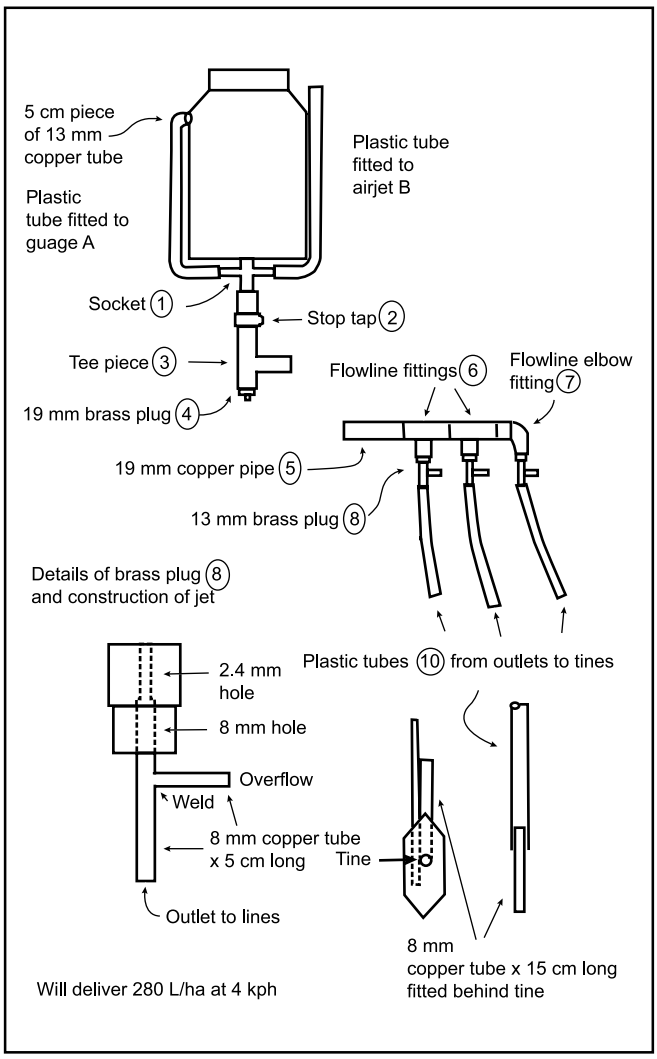
The next step is to construct the jets. Drill a 2.4 mm hole halfway through the three 13 mm brass plugs (8), and an 8 mm hole through the other half. Cut six pieces of 8 mm copper tube, 5 cm long. Drill one 6 mm hole through one side of three of these pieces, 19 mm from one end, and over these holes weld the other three pieces to form a tee piece.

Weld one of these into the 8 mm hole in each of the three brass plugs (8), then screw these plugs into flowline fittings (6) and (7). This completes construction of the machine.

Fit plastic tube to gauge A and air compensating jet B and from outlets to tines. This can be done more easily if the ends of the plastic tube have been immersed in hot water for a few minutes.

Fit the 15 cm lengths of 8 mm copper tube into the ends of the plastic tubes, and attach behind tines as shown in diagram.

This makes a three-row machine. Should more rows be needed add more flowline tees (6), complete with jets.



Construction of gravity flow fumigator.

The machine is now ready for use. Turn off stop tap, and fill drum with fumigation liquid. When tap is turned on, all plastic pipes should be filled and flow freely at the outlets.

If the outlet pipes on the tines block, the liquid will overflow at the plastic overflow pipe on the jet. Make sure the lid is down tight and all fittings are tight.

At 4 km/ h this will give 280 litres per hectare.

REGISTERED FUMIGANT AND NON-FUMIGANT NEMATICIDES IN NSW

Important: Pesticides Act 1999

Pesticides listed here were registered at November 2002 (Source: Infopest November 2002). Note that you must use only a currently registered pesticide, and it is not to be used for any purpose or in any way contrary to the directions on the label, unless a permit has been obtained under the Act.

WARNING: *Application of methyl bromide and chloropicrin in NSW can only be made by fumigators who hold certificates of competency as set out in relation to that work in the National Standard for Licensing Pest Management Technicians.*

Application of Telone® in NSW can only be made by fumigators accredited under the Telone® training program.

Applicators of metham sodium and dazomet in NSW are advised to attend the registrant's training program managed by Agsafe.

Application of Temik® in NSW requires users to attend a training program and be issued with an Aventis CropScience Certificate of Accreditation prior to purchase and use.

Fumigants: The following soil fumigants are registered in NSW, Australia.

Dazomet (Basamid ® Granular) – A general low volatile sterilising fumigant which releases methyl isothiocyanate (MIT) gas. Formulated as a fine powder, which is broadcast and then cultivated in.

Metham sodium (Chemfarm Metham ®) – a liquid, low volatile, water soluble fumigant that breaks down to MIT gas in soil.

Methyl bromide – extremely volatile, the gas rapidly disperses in soil. The gas is highly toxic to humans. It kills weed seeds as well as most pest and disease agents. Must be applied under gas tight conditions. The product will be phased out by 2005.

1,3 - Dichloropropene (e.g. Rural Telone * C-35) – a liquid fumigant and highly volatile that will need surface sealing after application, may increase ammonium nitrogen level in soil after application, suppresses weeds.

Chloropicrin – a granular fumigant, less volatile but highly dispersive into soil, highly toxic to humans, needs soil surface sealing immediately after application.

Crops and plants that Nemacur can be used on in NSW

Before or at planting		After planting
A. Crops that can be treated with liquid formulation		
Banana	Lettuce	Banana
Beet root	Mushrooms	Citrus
Carrots	Onions	Grapes
Celery	Ornamentals (annuals)	Ornamentals (perennial)
Citrus	Potato	Potato
Crucifers	Strawberry	Turf
Cucurbits	Sweet potato	
Flower bulbs &/or Corms	Tomato	
Grapes	Turf	
B. Crops that can be treated with granular formulation		
Banana		Banana
Ornamentals (annuals)		Flower bulbs &/or Corms
Potato		Ornamentals (Perennial)
Tomato		Turf
Turf		

Non fumigant nematicides: The following nematicides have been registered in NSW for using on different crops. Fenamiphos is the only nematicide that can be used in vegetable crops in NSW.

Cadusafos (Rugby ® 100 G,Granular) – Registered in NSW to control nematodes in banana, citrus and tobacco.

Aldicarb (Temik ®, Granular) – Crops that can be treated to control nematodes in NSW are sugarcane, oranges and mandarin.

Oxamyl (Vydate ® L) – A water soluble liquid nematicide that can be used to control nematodes of banana in NSW.

Terbufos (Hunter® 150G, Granular) – Registered in NSW to control nematodes in banana, wheat and barley.

Fenamiphos (Nemacur ®,Granular or liquid) – A general nematicide that has been registered to control soil borne plant parasitic nematodes in a wide range of crops in NSW e.g. most vegetables, cucurbits, banana and banana planting material, citrus, grapevines, mushrooms, ornamentals, flower bulbs and corms and strawberries. Commercially it is available as Nemacur ® 400 (liquid) or Nemacur ®100G (granular). The crops / plants that can be treated with Nemacur ® in NSW are tabled on page 9.

FURTHER INFORMATION

This edition of Agfact incorporates information from the second edition of *Root knot disease, 1985, Root knot disease – chemical control measures,1988,(R. W. McLeod) and Managing soil-borne diseases in vegetable crops following the withdrawal of methyl bromide,1999, (Graham R. Stirling and Marcus G. Ashley, Biological crop Protection Pty Ltd., 3601 Moggill Rd., Mogill, QLD 4070).*

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