Advisory Leaflet **460**
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MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Stem Eelworm on Narcissus

Photo: *Plant Pathology Laboratory*

1. Narcissus foliage affected by stem eelworm; middle leaf shows typical spickels

STEM EELWORM* is a pest well known to most bulb growers and is of particular concern to those who grow narcissi for export. It is a pest of many other plants, including various farm crops (see Advisory Leaflets 178 and 409), vegetables (Advisory Leaflet 440) and strawberries (Advisory Leaflet 414).

Several apparently distinct 'races' or 'strains' of stem eelworm occur on different crops. Some races breed readily on a wide variety of plants, while others are more specialized; sometimes the host ranges of two or more races overlap. Races can only be distinguished by their ability to multiply on various host plants and their effects on these plants. However, their attacks are not limited to their most suitable hosts, and **stem eelworms of any race may enter and**

**Ditylenchus dipsaci* (Kühn) Filipjev

survive in, or even breed slowly in, a wide variety of plants. Thus there is no guarantee that plants considered 'safe' in rotation with bulbs will remain so.

At least three races are known specifically to infest bulbs in Britain, i.e., the narcissus, tulip and hyacinth races. The narcissus race attacks narcissi and tulips but does not breed so freely in tulips as does the tulip race and symptoms are less pronounced. The narcissus race is common and very important commercially in both eastern and south-west England. The tulip race (see Advisory Leaflet 461) can infest tulips, narcissi and hyacinths; it occurs mainly in eastern England. The hyacinth race is rare in Britain; occasionally it has occurred in the south-west of England. It does not affect narcissi or tulips. Each of these races can attack certain other kinds of bulb.

Description and Life History

The adults are tiny, thread-like, transparent worms, which reach a length of about 1·2 mm; they cannot normally be seen without magnification. Both males and females live as parasites within the plant tissues where they often occur in enormous numbers. The females lay many eggs, and the newly hatched eelworms, apart from their smallness, closely resemble the adults in appearance. Breeding is rapid and continuous as long as the host plant remains alive. Eelworms frequently leave infested bulbs and migrate to adjacent ones through the soil. This migration may continue if the bulb dies, but many of the eelworms will probably die in the decaying remains.

Eelworms can also breed in stored bulbs; heavily infested bulbs are often killed and become completely rotten. Great numbers of eelworms then find themselves without any further food supply. Under these conditions many of them do not develop beyond the pre-adult stage, when they are particularly resistant to unfavourable conditions. Thousands of these pre-adult larvae, forming glistening, off-white masses easily visible to the naked eye, may sometimes be found oozing out at the base of a rotten narcissus bulb. These masses of eelworms gradually dry to form pieces of dirty white or buff-coloured material known as 'eelworm wool'. Mycelium of *Fusarium*, which also occurs frequently around the base of rotted bulbs, differs from eelworm wool in being pure white and more fluffy in appearance (Fig. 2).

In this dormant condition the eelworms can remain alive for several years, becoming active again only when moistened. Small particles of infested bulb tissue blowing about from bulb stores or carried into fields with bulbs

Photo: *ADAS, Kirton*

2. The basal parts of two bulbs showing a piece of buff-coloured 'eelworm wool' on the upper one and white mycelium of *Fusarium* on the lower one

can quickly start fresh infestations; infested fragments can similarly contaminate cleaning, grading or other machinery and thus spread infestation to clean bulbs. Pieces of leaf infested with dormant eelworms can also be a means of spread, especially when tops are 'flailed' off. The 'wool' stage is more resistant to hot-water treatment than the active stages.

This dormant or quiescent stage in the life history is characteristic of all races of the stem eelworm and makes it the more persistent and insidious. However, the eelworms seldom remain dry for long in the field and they cannot live in moist soil for much more than a year without food plants.

Nature of Injury

Eelworms usually enter the bulbs from the soil in the region of the neck, the initial infestation often being caused by only a few eelworms. They invade the young leaf tissue and some are carried upwards by growth of the leaves while others move down into the leaf bases. The establishment of small breeding colonies in the leaves leads to the formation of small local swellings or spickels (Fig. 1). These are usually conspicuous by their unhealthy pale yellow colour but, with slight infestations, they may be more easily recognized by the unevenness felt when the leaf is run between finger and thumb. In more severe cases, the spickels may be large and show brown areas of dead tissue in the centre of the swelling. When leaves are heavily infested, the spickels tend to run together and the whole leaf becomes twisted, distorted and discoloured. Flower stalks are affected in the same way as the leaves: they often have spickels and in severe cases are misshapen and stunted. **Eelworm-infested bulbs often flower late, so that a late-flowering patch is sometimes a sign of eelworm attack.**

Although eelworms may invade bulbs at any time during the growing season when conditions are suitable, invasion occurs mostly during the cooler months and often before the leaves emerge above ground. When the attack occurs late or is slight, spickels may not appear until after flowering or may not show at all during the first year of growth. Thus the absence of symptoms, especially in one-year-down bulbs, cannot be taken as a sure sign that the stock is eelworm-free. **Bulbs selected as apparently healthy from a stock in which some are infested are likely to harbour eelworms. A stock in which eelworm has been found should be regarded as infested and treated as such.**

As the season progresses, the eelworms multiply in the leaf tissue, particularly in the basal parts of the leaves. When the foliage begins to die, or before, they spread downwards into the scale leaves of the bulb. This initial infestation of the bulb usually leads to orange-brown or greyish-brown areas in the infested scale leaves. If a bulb at this stage is cut across just below the neck, only a small patch of discoloured tissue may be visible in one scale where the eelworms are feeding. Later the infestation will spread right round an affected scale, the eelworms taking the line of least resistance and spreading as far as possible before moving to an adjacent scale. Spread from scale to scale is usually via the base plate of the bulb; after destroying one scale, the eelworms enter the base plate and then work upwards into the adjacent scale. This behaviour accounts for the characteristic brown rings seen when heavily infested bulbs are cut across (Fig. 3) and the loosening of the base plate to form a plug of infested tissue which often remains in the soil at lifting.

Infested bulbs tend to become soft in store, particularly around the neck, and usually appear dull by contrast with the lustrous appearance of healthy bulbs. They are often secondarily attacked by bulb mites and the small narcissus fly

Photo: *Plant Pathology Laboratory*

3. Infested narcissus bulbs cut across to show the 'brown-ring effect'

(see Advisory Leaflet 183) (Fig. 3, right); presence of the latter is frequently an indication of eelworm trouble.

Other Plants Attacked

The narcissus race of eelworm which occurs in the south-west of England can infest and cause damage to snowdrops, bluebell and scillas. On snowdrops it produces spickels similar to those found on narcissi; on bluebells and scillas it causes stunting and twisting of leaves and flower stalks, with pale streaks and lesions on the leaves. The effects of an attack on hyacinths are rather similar to those on narcissi, except that definite spickels are not usually formed on the leaves.

Stem eelworms from narcissus may also breed and persist in onions, broad beans, French beans, runner beans, peas and strawberries. Brassica seedlings permit eelworm breeding but the eelworms seem not to persist in them; brassica transplants may help in eelworm spread and should not be propagated on infested land. Cereals and grasses seem unable to maintain the eelworm.

Weeds. Stem eelworm has been found in most common weeds growing in fields where bulbs have been infested. Examples are goosegrass (cleavers), chickweed, rayless mayweed, speedwells, knotgrass, bindweed, groundsel and scarlet pimpernel. Some of these weeds may maintain the eelworms in the absence of host crops, though there is little if any evidence of their practical importance.

Means of Spread

The commonest way in which this eelworm is spread is by the distribution and planting of infested bulbs. It can also be spread about farms or gardens in pieces of dead foliage, bulb debris and in soil, which may be blown about or carried on implements and

vehicles. Within fields, infestations generally extend slowly in the soil so that a small patch of infestation gradually increases in size. This kind of spread is increased in the direction of cultivation and may be greatly accelerated by movement of surface water—an effect which is sometimes clearly seen on a sloping field, where eelworm-infested patches are elongated in the direction of the slope. Spread by cultivations can be very serious. On sloping fields cross-cultivation makes the situation worse by extending infestation sideways and starting new concentrations, which may then be spread downhill by surface water.

Cultural Control

As with other pests and diseases, sound crop rotations, hygiene and use of healthy, good quality planting material do much to prevent crop losses due to stem eelworm.

Growers are advised to walk their stocks during the growing season, keeping a sharp look-out for suspicious plants and calling in a local ADAS adviser when necessary. Eelworm is far more easily detected on the foliage than in the dry bulbs. When inspecting stocks of narcissi for eelworm, it is advisable to avoid days when there is bright sunshine because contrasting shadows make it more difficult to see the spickels. The best time to detect eelworm is just after flowering.

Spread of eelworm can be reduced by roguing out plants from infested areas as these are discovered, instead of leaving them to spread the pest further in the stock. It must be emphasized, however, that this is only a check and stocks should subsequently be given hot-water treatment (see below). Removal of visibly infested bulbs after lifting improves the efficiency of the treatment.

Bulbs left behind as groundkeepers should be removed when they show in the following spring; **only then should the rotation period be considered as having started.** The interval between one bulb crop and the next should be at least three years, preferably longer, ensuring that no other susceptible crop is grown in the interval and that weeds are kept to a minimum.

Hot-water Treatment*

Hot-water treatment is a long-established and efficient method for control of eelworms and other pests in narcissus bulbs. It was originally introduced to control the large narcissus fly (see Advisory Leaflet 183). The present recommendation for eelworm control is to soak the bulbs for three hours in water at 44·5°C (112°F) during the period between lifting and replanting. The treatment should be timed from the moment the water temperature reaches 44·5°C after the insertion of the bulbs. Because of the risk of damage to the bulbs, particular attention should be paid to the stage of development of the bulbs at which treatment is applied (see below). The degree of hot-water damage is also greatly influenced by the storage temperature during the 2–3 weeks before treatment. When treatment is correctly timed damage is unlikely provided bulbs have been held at 17–18°C (62·5–64·5°F), but yields can be decreased considerably if storage is below 16°C (61°F). Bulbs for forcing should not be hot-water treated.

BEFORE TREATMENT

Warm storage of bulbs at 30°C (86°F) for a week, or at 35°C (95°F) for five days, just before hot-water treatment considerably reduces subsequent damage to flowers and foliage and also has a beneficial effect on growth. It has made possible safe treatment of bulbs at a higher temperature than previously, e.g., 45·5–46·5°C (114–116°F) for three hours.

*See also STL 21 *Hot-water Treatment of Narcissus Bulbs*

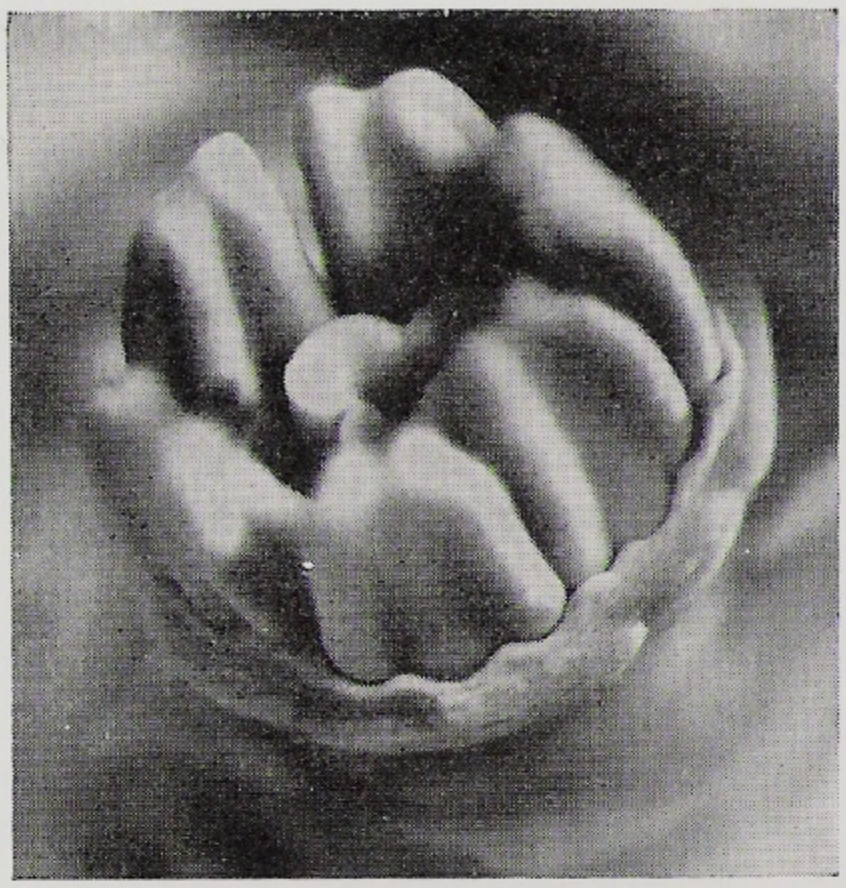

Photo: *Plant Pathology Laboratory*

4. Ideal development stage of narcissus flower for hot-water treatment. Petals have been cut away to show carpels, stamens and trumpet initials (×15)

For this reason a higher water temperature in conjunction with a pre-soak (see below) is essential if high-temperature storage is used. This warm-storage treatment should not be given to known infested stocks.

Pre-soaking entails soaking the bulbs for 2½–3 hours in cold water (with a wetter and formalin added) immediately before the hot-water treatment. This process helps to drive out air bubbles that might otherwise insulate eelworms; it also wets and reactivates eelworm 'wool', making control a little easier. However, pre-soaking, especially with a wetter added to the water, increases the damage caused by subsequent hot-water treatment unless the bulbs have been warm-stored as above.

TIMING OF TREATMENT

The timing primarily affects the risk of damage to the subsequent crop, but it can also influence the degree of eelworm control. Bulbs from infested stocks should be lifted before the foliage has died and treated as soon as possible to destroy the eelworms before they reach the resistant 'wool' stage. The subsequent flower crop will almost certainly be damaged by this early treatment, but eelworm is such a serious menace that many bulb growers are prepared to sacrifice a flower crop to ensure clean bulbs.

Precautionary treatment of apparently uninfested stocks of bulbs lifted at the normal time can be started as soon as the bulbs have been cleaned and graded but must be completed by late August before the root initials have started to grow. Early treatment damages the flowers but does not affect bulb yield. If it is intended to crop flowers in the first year after replanting, hot-water treatment should be applied as soon as the flower buds are fully developed within the bulb (Fig. 4). Sample bulbs must be cut to determine the flower-development stage. This is not difficult using a ×8 hand lens, but expert advice should be sought if in doubt (see also Technical Bulletin 22: *Internal Stages of Bulb Development*.*)

Pale blotching of the upper parts of the leaves caused by late treatment is sometimes confused with the effects of the virus disease 'mosaic' or 'stripe', but the markings due to this disease are lines rather than blobs and are more evenly distributed.

The order in which different varieties flower does not indicate the order in which they should be hot-water treated, i.e., the late poeticus types should be treated first, followed by short cup, large cup and trumpet varieties in that order. Doubles should be treated according to their origin, e.g., double whites being poeticus sports should be treated early.

EQUIPMENT AND OPERATION

Many instances of unsatisfactory hot-water treatment could undoubtedly be traced to inefficient hot-water tanks, incorrect use of the installations, or to

*Obtainable from HMSO, P.O. Box 569, London SE1 9NH, or through booksellers price 17½ pence (by post 24 pence)

lack of hygiene leading to reinfestation. The following are some of the most important requirements:

1. Efficient forced circulation of the water.
2. Good heat insulation over the whole tank.
3. Accurate temperature control (preferably by an automatic regulator).
4. An accurate thermometer of the mercury-in-glass type (*not* one encased in metal or other material).
5. A clean, draught-free building to house the equipment.
6. A good wetting agent added to the water.
7. A fungicide added to the water to prevent bulb rots and other fungus troubles: commercial formalin at a strength of 1 in 200 or a suitable proprietary material may be used. Formalin also helps to kill eelworms present in the water and should always be used whether or not another fungicide is added.
8. Where bulk-handling systems are not used rigid open-mesh containers, bulb trays or nets for the bulbs, but *not* close-woven sacks. Plastic or cotton nets are widely used in commerce. They should always be tightly filled so that, when the tank is loaded, spaces are present between the nets for water circulation.
9. With bulk-handling systems, using e.g., 400 kg (8 cwt) wooden boxes having slatted floors, water circulation, temperature control and post-treatment drying all require special attention.
10. Tanks must not be overloaded: too many bulbs impede circulation and make temperature control more difficult. A ratio of bulbs to water of 1:2 should never be exceeded; a ratio of 1:3 or more is ideal.
11. Strict attention to hygiene. Frequent hosing down of the building, a 'one-way traffic' system and new or sterilized containers for treated bulbs are recommended. However, with front loading (and some bulk-bin treatment tanks) a one-way system is not possible. With bulk handling, treated bulbs remain in the same containers throughout so that the latter are treated with the bulbs.

All growers wishing to instal new hot-water tanks or to improve their existing ones should get more detailed advice from the local ADAS advisers.

AFTER-TREATMENT CARE

After treatment, bulbs should be cooled quickly. Ideally they should be planted at once; if this is not possible, they must be dried thoroughly as soon as possible after cooling.

Treated bulbs should of course never be planted on infested land. Long rotations and clean cultivation reduce the risks of reinfestation—see *Cultural Control* on page 5.

Chemical Treatment

TREATMENT OF BULBS

Treatment with thionazin has proved effective for tulip but is not recommended for narcissus.

TREATMENT OF SOIL

Although chemical treatments of the soil against eelworm are not an economic proposition for large areas, it may sometimes be worth treating small patches, after lifting and destroying the affected bulbs together with a margin of surrounding healthy ones, to eradicate a slight infestation before it spreads. Since soil fumigation alone tends to be less effective in the surface layers of soil, the best results are obtained when soil fumigation is followed by a liquid nematicide drench applied in sufficient quantity to wet the top 5–8 cm. Dichloropropene alone or in mixtures has proved effective as the soil fumigant, but other nematicides or soil sterilants, such as dazomet or metham-sodium, could be used. For the surface drench, proprietary products based on xylenol, cresylic acid or other phenolic compounds are suitable. Growers who want advice on the possibilities of soil treatment should consult the local ADAS advisers.

Single copies of the Advisory Leaflets mentioned in this leaflet may be obtained free from the address overleaf.

Precautions

Whenever pesticides are used, *read and follow carefully the instructions on the label.* Users should also consult the 'Recommendations for the Safe Use of Chemical Compounds Used in Agriculture and Food Storage' published by, and obtainable free from, the Ministry of Agriculture, Fisheries and Food, Environmental Pollution, Pesticides and Infestation Control Division, Great Westminster House, Horseferry Road, London SW1P 2AE.

Use the chemicals mentioned in this leaflet with care. Dazomet, dichloropropene and metham-sodium are strongly irritating to the skin, eyes, nose and mouth.

Store new and part-used containers in a safe place under lock and key. Wash out empty containers thoroughly and dispose of them safely. Do not contaminate ponds or waterways with chemicals or used containers.

Proprietary products based on chemicals used for pest, disease and weed control can be officially approved under the Agricultural Chemicals Approval Scheme. It is strongly recommended that approved products should be used. Approval is indicated on the containers by the mark shown here. A list of Approved Products is published in February of each year and is obtainable free from the address below or any Regional or Divisional Office.

AGRICULTURAL CHEMICALS APPROVAL SCHEME

Photograph reference nos.: Fig. 1—J 621/2; Fig. 3—J 1606/11 & 4;
Fig. 4—M 1596

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