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Narcissus Pests

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Narcissus Pests

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Foreword

THE growers of Narcissus have been very fortunate in that the pests of this valuable crop have received specialist attention for nearly forty years. Names like W. E. H. Hodson and L. N. Staniland, both past authors of this Bulletin, rank high in the list of pioneer researchers on bulb pests in this country. They have been followed with no less enthusiasm by the contributors to this sixth edition which brings up-to-date our knowledge of the important pests of the crop and tested and practical methods of control.

Although the present Bulletin mainly follows the pattern laid down by Mr. Hodson in 1932 many sections have been extensively rewritten. Mr. H. C. Woodville has dealt with narcissus flies as he did in 1958, and Mr. H. G. Morgan with detection of pests in the field, stem and other eelworms and their control. Mr. A. L. Winfield covered bulb scale mite and the general problem of hot-water treatment of bulbs, and chemical dips to control stem eelworm, and also contributed the notes on miscellaneous pests. Mr. P. Aitkenhead dealt with bulb mites. Mr. J. F. Southey provided the section dealing with eelworms as vectors of virus diseases of the crop. The Bulletin was under the editorship of Mr. P. Aitkenhead, assisted by Mr. H. W. Janson.

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December, 1969

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Introduction

In 1967 about 7,400, in 1969, 8,700, acres of England and Wales were devoted to the commercial cultivation of Narcissus, of which over 3,000 acres were used for the production of bulbs for resale. By comparison with other bulb flowers Narcissi account for by far the greatest area, and this commercial acreage is matched by few other countries, even including the Netherlands.

The pleasant variety of form shown by this easily recognizable group of plants, their value as a spring flower and their ability to grow in a wide range of soil conditions and climate are all good reasons for their popularity. Furthermore the generally moist and mild maritime climate of these islands appears to encourage the growth of firm, solid bulbs which are productive, yet of moderate size.

A specialist grower's stocks of bulbs in themselves represent a heavy capital investment. For example, a good and popular variety like Golden Harvest or Fortune may be worth £600–£1,000 per acre planted; the more highly-prized varieties may be worth far more, while a single bulb of a new and promising variety may cost £150. The producer depends on the vegetative increase of bulbs each year to renew his capital and also to provide capital gain in the form of saleable bulbs. Unfortunately, the use of vegetative propagation provides an easy means for the transmission of disease and pest organisms from one generation of bulbs to the next and from one place to another. Our basic aim, as it was of Mr. W. E. H. Hodson who wrote the first edition in 1932, is to help the grower to counter the introduction and build-up of pests and thus to help maximize bulb increase. While the contents and their order have changed considerably since the first edition the authors of this latest edition have followed Mr. Hodson's principle of providing both practical advice and background knowledge.

Many of the improvements in practical control that are here included have developed from research and testing by specialists. Most of the references under 'Further Reading' at the end of each section give access to specialized studies on many topics. These are of interest in themselves and, in turn, provide references to much more of the technical literature on bulb pests.

Detection of Narcissus Pests in the Field

H. G. Morgan

The growing narcissus crop is subject to many factors which affect its growth, pests being only one facet of ill-health. Final diagnosis of many attacks can only be made by laboratory examination, but informed observations in the field can be extremely useful in directing suspicion towards certain pests. Stocks of bulbs form a very considerable capital asset, and any deterioration in their health involves a wasting of capital, as well as a reduction in income from the crop. Time spent in safeguarding the health of the crop is time well spent, and the earlier a diagnosis is made, the easier it is to prevent spread and plan control measures. If each stock is examined on several occasions throughout the season, and notes made of any suspicious features, the sources of trouble can be pin-pointed; this in turn can show where techniques have failed and where improvements in methods can not only save the failing crop, but prevent the trouble spreading to as yet unaffected stocks. The following section attempts to cover the various symptoms of pest damage which may be seen at the various stages of growth and notes briefly the causes of other symptoms which might be confused with pest damage. For details of diseases, reference should be made to Bulletin 117, *Diseases of Bulbs*.

EXAMINATION AT THE TIME OF EMERGENCE

The first indications of ill-health in a crop appear at the time when the majority of plants are showing through the soil, and observations should start at this stage. It is easy to detect patchiness at this stage, for there may be areas where no leaves are visible, though the rest of the field is green. This may be only a result of variations in depth, moisture or structure of the soil, but it is a warning to keep the field under close observation until the crop is proved healthy.

If the bare patches persist for more than a few days, the first step is to dig up some bulbs from the backward areas. The condition of the roots will give the first clue—healthy bulbs have a uniform ring of clean white roots emerging from the baseplate. Absence or extreme irregularity of the ring of roots is an indication that the developing roots have been destroyed by some pest or disease, by chemical toxicity, or by faulty handling of the bulbs prior to planting. If the roots are present, but partly brown or rotting, some form of root-rot should be suspected; roots may rot in waterlogged or oxygen-starved soil, but the 'root-rot' complex generally involves the root-lesion eelworms *Pratylenchus*, as well as fungi. At this stage of the season, it may be possible to see small black slits running along the otherwise clean root; these slits show the presence of *Pratylenchus*, and samples of the affected bulbs, with the soil immediately surrounding the roots, should be sent, preferably in polythene bags, to the nearest N.A.A.S. laboratory for microscopical examination.

Symptoms of pest damage may also be seen on the shoot. There should be a pair of leaf-tips emerging from each 'nose' of the bulb, surrounded by a sheath at their bases, growing up straight and closely pressed together. They may be delayed and distorted by growing through stony ground, but this will have been noted when they were dug up. If parts of the leaf have been eaten away, slugs are probably responsible and will be found in the soil. Discoloration and distortion may be due to chemical damage, but short, swollen 'puffy' leaves, sometimes accompanied by a slimy rot, give a suspicion of the presence of eelworm.

When the external symptoms have been noted, the bulb should be cut across at its widest point and the cut surface examined. Many types of pest and disease damage lead to the destruction or browning of parts of the tissue.

PRESENCE OF GRUBS, ETC.

Large narcissus fly attack is easily recognized by the presence of a single large grub in the centre of the bulb, surrounded by frass and damaged tissue, while the outer layers of the bulb are undamaged. If many small grubs are present in a bulb with extensive rotting, the attack will be by small narcissus fly or some other scavenger, and this is evidence that the bulb was damaged or otherwise unhealthy before the attack. If decay has set in, the bulb may also be infested by bulb mites (which grow to the size of a pinhead and are often present in very large numbers), or by scavenging worms, eelworms or fly grubs. In all these cases, some other original cause of damage should be sought.

BROWN RINGS

Brown rings in the bulb are usually evidence of stem eelworm attack; the centre of the bulb and the outer layer of scales usually remain clean except in very heavy infestations. Sometimes, particularly in varieties with some *Narcissus tazetta* blood, narcissus eelworm produces only scattered necrotic patches instead of full brown rings. Similar symptoms are found in the rare cases of attack by the narcissus bulb and leaf eelworm (*Aphelenchoides subtenuis*), which may also cause distortion of the outer scales. Brown ring symptoms confined to the outer scales do not usually indicate the presence of eelworm; this type of damage occurs where the bulbs have been exposed to sun-scald or unfavourable soil conditions, and some fungus diseases may produce a similar effect.

BROWN SPOTS

Scattered brown spots in the cross-section may be caused by various types of local damage, including hot-water damage. There is one pest, however, the bulb scale mite, which causes characteristic brown spots at the angle of the scales.

When a transverse cut has shown the presence of decay symptoms in a bulb, it is often useful to cut lengthwise through the discoloured area. In the case of bulb scale mite, the spot will be found to be due to a brownish roughened area on the surface of the scale, usually with very small mites feeding on it. From the extent of the symptoms in other cases, it is usually possible to determine whether the attack is spreading downwards from the neck or upwards from the baseplate, and this will help in deciding what pest or disease is responsible.

SYMPTOMS IN GROWING FOLIAGE

At later stages of growth it is possible to see abnormal symptoms on the developing foliage and flowers. Yellowed, discoloured or distorted foliage may be caused by a wide range of factors. Anything which affects root development may have a depressing effect on the growth of the foliage, and viruses and herbicide damage have specific effects on the leaves. Limp, yellowed leaves may result from bulb scale mite attack; the leaves or flower stem may have brown 'saw-tooth' markings along their edges and in extreme cases the leaves may fail to appear, leaving only the flower to emerge from the ground. Swellings on the leaves may be spickels caused by eelworm attack, but microscopical examination is needed to distinguish them with certainty from damage caused by temperature shock. Swollen 'puffy' leaves are also evidence of eelworm attack.

'Grassy' foliage is well described by the name; it appears healthy, but instead of the few broad leaves of a normal plant, there are dense tufts of abnormally narrow leaves. This is a symptom of narcissus fly damage, and somewhat similar symptoms may be seen in the physiological disorder known as 'broodiness'. Distorted leaf growth, often curving abnormally back towards the ground, may follow damage to the neck of the bulb, but is also found when bulbs have been planted too close to the surface.

There are a few fairly characteristic symptoms to be seen on the foliage. Browning and death of the leaf-tips is not usually caused by pests but more often by frost, herbicides, or fungi such as *Stagonospora*. Pale spots, usually sharp-edged and up to $\frac{1}{8}$ inch (3 mm) in diameter, occur on the leaf an inch or so below the tip; this is a very characteristic sign following hot-water treatment. Chevron-shaped areas of minute pale spots, just below the leaf-tip, may be caused by the feeding of the bulb scale mite, which should then be searched for in the neck of the bulb. Saw-toothed marks on the edges of the flower stem, or on the edges or midrib of the leaf, are another characteristic symptom of this pest.

SYMPTOMS ON THE FLOWERS

Apart from caterpillars and slugs which eat the flowers, pests are seldom responsible for particular symptoms on flowers. Flowers with splitting of the trumpet, and sometimes of the petals also, have been damaged by hot-water treatment at the wrong stage of growth. Failure to open, sometimes with fusion of the petals into a 'balloon', is characteristic of some types of herbicide damage. Discoloration and rotting of the flowers within the sheath is usually caused by fungi, though sometimes bulb scale mite attack may produce this effect. Failure of the flower stem to elongate may be due to physical factors but may indicate the presence of eelworm or some other pest.

SYMPTOMS OF GROSS DAMAGE

To complete this survey of the detection of pests in the field, it should be noted that gross damage to bulbs, foliage and flowers may be caused by the feeding of slugs and snails, caterpillars, leaf-miners, birds and rodents. In all these cases the damage itself will be clear and there should be little difficulty in assigning a cause. Likewise, heavy attacks of aphids may occur on foliage or bulbs, and the cause and cure are again obvious.

SUMMARY OF SYMPTOMS

Brief descriptions of the various symptoms of pest attacks, and other symptoms that may be confused with them, are summarized in the following section. These are only indications and, when a particular pest is suspected, they should be supplemented by reference to the fuller description in the section on the pest.

SYMPTOMS	CAUSES
Damage in patches in the field	
Plants missing or severely distorted (bulbs when lifted are rotting or with brown rings).	Stem Eelworm
Growth of plants retarded with yellowing or rotting of leaves but no distortion (bulbs with outer scales rotting).	Waterlogging **or** Fungus Disease
Growth of plants retarded but otherwise normal (bulbs intact but roots missing or brown and rotting).	Root-Lesion Eelworms
Plants flowering late or with short stems (bulbs when lifted show brown rings or patches).	Stem Eelworm
Damage to scattered plants through the crop.	
Plants with swelling or distortion on leaves or stems.	Stem Eelworm **or** HWT damage
Plants with no flowers, but large numbers of narrow 'grassy' leaves.	Large Narcissus Fly
Plants with few or no leaves, flower alone showing, and often early.	Bulb Scale Mite
Damage to foliage.	
Leaves with scattered whitish spots in area below tip.	HWT damage
Leaves with pale stippling, often in the form of an inverted V, just below the tip.	Bulb Scale Mite
Leaves with pale streaks, or with rusty mottling at the base.	Virus **or** other diseases **or** Herbicide damage
Leaves uniformly bright yellow.	Herbicide damage
Flower stem, or sometimes leaves, with brown 'saw-toothed' edge (flowers often fail to open).	Bulb Scale Mite
Damage to flowers.	
Flowers with petals and cup reduced, split or narrowed.	HWT damage
Flowers fully developed but fail to open, swelling into a 'balloon'.	Herbicide damage
Flowers remain within the sheath, and may later rot.	Bulb Scale Mite **or** Fungus Diseases
Flowers remain green, and do not fully expand.	Virus **or** genetic disorder
Damage to bulbs (cut across and then lengthwise through damage).	
Brown rings or patches.	Stem Eelworm **or** Narcissus Bulb and Leaf Eelworm
Small brown spots at the angles of the scales only.	Bulb Scale Mite
Brown rings affecting the outer scales only.	Waterlogging **or** Fungus Diseases
Baseplate completely rotted and rot spreading upwards.	Fusarium **or** other Fungus
A single large grub in the bulb.	Large Narcissus Fly

SYMPTOMS	CAUSES
Many small grubs in the bulb, which is usually wet and rotten	Small Narcissus Fly **or** scavenging grubs following damage
Bulb tissue dry and disintegrating, with many small animals up to the size of a pinhead.	Bulb Mites

Narcissus Flies

H. C. WOODVILLE

THERE are two flies that attack the narcissus crop, the large and the small narcissus flies.* The latter actually comprises two very similar species which, from the grower's point of view, may be regarded as the same. There are also several other similar looking flies which can be confused with these two pests of the crop.

LARGE NARCISSUS FLY

The large narcissus fly, *Merodon equestris* (F.), is a member of the family Syrphidae, which includes the insects known as hover flies and drone flies. This fly is a major pest of narcissus, especially in south-west England, and it causes severe losses throughout much of Europe and North America.

The original home of the fly is believed to be southern Europe. It was first definitely recorded in England in 1865, since when it has become widespread and a serious pest.

IDENTIFICATION

The adult fly (Plate I) is a conspicuous insect nearly ½ in. (12 mm) long, with a stout hairy body, and having a general resemblance to a small bumblebee. Individual flies differ considerably from one another in appearance owing to variation in the colour of the hair. Some individuals are almost entirely tawny and thus resemble honeybees or drone flies, some are boldly banded on the thorax and abdomen with red, orange and grey, and others are entirely black except for the abdomen, which may be banded with any one of the above mentioned colours. These colour variations are of little relevance here, except that as a result of some of them a number of other insects, notably the beneficial ones such as bees, bumblebees and drone flies, are often mistaken for the large narcissus fly. The narcissus fly, like all true flies, differs from all bees by having only one pair of wings; bees have two pairs, although they may appear to have only one, for the front and hind pairs are linked together during flight. The narcissus fly differs from drone flies by being more hairy and having on the underside of the femora of the hind legs a prominent broad tooth-like process. The male fly has also a sharp spur on each hind leg. The legs are invariably black. The eyes are very large, reddish in colour and in the male meet in the centre of the face.

The egg is very small, being approximately $\frac{1}{16}$ in. (1·6 mm) long. It is oval, tapering slightly towards one end, and is pearly-white.

The larva is legless. When newly hatched it is a little larger than the egg, almost transparent and sparsely covered with long spine-like hairs. As it

*See also Advisory Leaflet 183, available from the Ministry (p. 40).

grows these hairs become less prominent and the general colour becomes yellowish. The larva is cylindrical in shape tapering slightly towards the anterior end. The hind end bears a short horny projection, dark brown to black in colour, which carries the main breathing pores. When the larva is extended, a pair of minute hooks, used to scrape off plant material, can be seen protruding from the mouth on the underside.

A full-grown larva (Plates III and IV) may be as much as ¾ in. (19 mm) long. It cannot then be confused with any other grub likely to be found in a narcissus bulb, but when partly grown it resembles the larvae of the small narcissus flies and of the fly *Syritta pipiens*. From all these it may be distinguished by the following characteristics: the central projection at the hind end is very dark in colour, whereas in the others it is almost invariably bright chestnut red; the projections on either side of the central one are minute but in *Eumerus* and *Syritta* they are quite conspicuous and more numerous; finally, the *Merodon* larva is usually found singly; the others are rarely found alone.

The tough leathery puparium (Plate I) containing the pupa, though shorter than the larva, is similar in shape. It is actually the last skin moulted by the larva and the central projection is still plainly visible.

LIFE HISTORY

The life cycle from egg to adult is completed once a year, and thus differs from that of the small narcissus fly which completes two or three generations per year. Adult flies appear in the open from about the third or fourth week of April to the end of June. When bulbs are being forced flies may be found as early as February, but these flies are unlikely to find suitable opportunities for laying eggs and from the practical viewpoint may be disregarded. Individual female flies live about 17 days and males about 11 days in captivity, and they probably have a similar length of life in the open.

In cool and dull weather the flies remain inactive in hedges, on banks, or in other cover in and around bulb fields. On bright days they fly actively over the drifts of narcissus, making a characteristic whining hum which is well known to commercial growers. Flowering shrubs, dandelions and other flowers in the vicinity of narcissus beds are visited frequently, and the flies sit sunning themselves on warm banks, tree trunks and foliage. Egg laying takes place only on bright, warm, windless days and has never been observed when the temperature in the sun has been less than 65 °F (18·3 °C). Each female fly deposits about 40 eggs during her life. She deposits her eggs singly, either in the soil very near the bulb, on the foliage near the neck or, if she can, on the bulb itself. To attempt to reach the bulb the fly walks down the crevice left in the soil by the dying down of the foliage and flower stems. It is unusual for more than one egg to be laid next to or on one bulb. The eggs are exceedingly delicate; in dry hot weather many laid in exposed situations shrivel, and few eggs hatch in cold, damp conditions.

Healthy eggs hatch in 10 to 15 days. On hatching out, the minute, very active larva makes for the nearest bulb, and attempts to burrow into it. Entry is almost always effected through the bottom or side of the baseplate, only occasionally through the scales, and all that can be seen after the larva has entered is a small rusty hole resembling a pin prick. During the first few weeks of its life the larva grows slowly while it tunnels in the baseplate. Eventually the tunnel is extended upwards into the succulent scaly portion of the bulb. Rapid growth now commences, and in a few weeks the whole of the centre of the bulb has been eaten, the larva living in the large cavity so formed (Plate III). As the larva grows it may eat out a tunnel from the bulb through the baseplate; this allows more space and also serves as an exit hole. Migration of larvae from bulb to bulb occasionally takes place if the food supply is exhausted, as when the bulb originally attacked was a small one. The winter is always passed as a larva in the bulb. In early spring the larva leaves the bulb through the hole previously cut in the base, or through the neck, and, in the soil some distance from the bulb and usually near the surface, it becomes a puparium. After 5 to 6 weeks the adult fly develops and emerges from the soil.

PLANTS ATTACKED

The narcissus is the principal host plant, but *Merodon* larvae have also been found in the following bulbous plants; *Amaryllis*, *Eurycles*, *Galtonia*, *Galanthus* (snowdrop), *Habranthus*, *Leucojum*, *Scilla* (bluebell) and *Vallota*; other recorded hosts are Dutch iris, *Iris xiphium* and *Cyrtanthus*. Tulip has also been mentioned as a host, but experience indicates that their attack causes such rapid decay of the bulbs that the larvae are unable to complete their development. Neither the wild bluebell nor the wild daffodil appear to be common hosts, but larvae are frequently found in the wild snowdrop (*Galanthus nivalis*), even in localities well isolated from bulb crops.

SYMPTOMS OF ATTACK

When bulbs are lifted they will each contain, if they have been attacked, a larva of the large narcissus fly, but this is not so easy to confirm at lifting time (July and early August) as the larvae are still small. However, even at this early stage of attack, many infested bulbs can be detected if the baseplates are first carefully cleaned of all dead tissue with a sharp knife. Where a larva has entered the baseplate a small rust-coloured mark is usually discernible, surrounding a tunnel a little larger than a pin in diameter. A little further careful cutting with a knife may confirm the presence of tunnels in the baseplate.

At planting time, usually September or early October, the larvae are in the centre of the bulb and fairly large. With a little experience infested bulbs may usually be detected at this stage by their greater 'give' between finger and thumb particularly in the region of the neck. All such bulbs should be rejected and destroyed (see page 11).

When an infested bulb has been planted one of two things is likely to happen. If the bulb is small it may fail to shoot and it subsequently dies. A moderately large bulb is rarely killed outright although the central growing point and flower may have been destroyed. These injuries stimulate numbers of adventitious buds to develop and in due course each of these buds produces foliage, but instead of the normal strong shoot, there appears a circle of smaller leaves, aptly termed 'grass'. When the damage is a little less severe the infested bulb may only send up weak yellowish and distorted foliage, which may resemble that caused by an attack of eelworm or bulb scale mite.

SMALL NARCISSUS FLIES

The small narcissus flies, although they do not look like the large narcissus fly, also belong to the family Syrphidae. Of the two species, *Eumerus tuber-*

culatus (Rond.), is the one usually found in this country in narcissus. The other species, *Eumerus strigatus* (Fall.), appears to be more frequently associated with injury to iris, hyacinth, parsnip and potato. In the past there was considerable uncertainty as to whether these flies were primary pests of narcissus. It is now felt that they seldom attack a narcissus bulb until it has been rendered unhealthy by some other cause. In most cases in Britain, an infestation indicates that the bulb has been attacked by stem eelworm.

Eumerus strigatus has been known in England since 1901 although it was known in Italy in 1857. During the past 40 years or so, both species have been reported from most countries in Europe and from North America. Since the adults and larvae of the two species look very alike and, in narcissus, have the same habits, for practical purposes they can be considered as one species.

IDENTIFICATION

The adult flies (Plate I) are about ¼ in. (6 mm) long. The body is short and thick set and the general appearance is very similar to some of the smaller solitary bees. The colour is black but the thorax shows greenish or bronze metallic reflections. There are three pairs of white crescent shaped marks on the abdomen and a white line on each side of the thorax. The egg (Plate III) is oval, only $\frac{1}{30}$ in. (0·8 mm) long, white and shiny. The larva (Plates III and IV) is longer in proportion to its breadth than that of the large narcissus fly and has a characteristic transparent skin. When fully grown it is about ⅓ in. (8 mm) long. At the hind end is the conspicuous horny breathing knob, bright chestnut red in colour. On each side of this are two smaller, easily seen projections. Beside these again, on close examination, can be found a much smaller pair of twin projections, together with a pair of simple projections intermediate in size between the two. These twin projections distinguish the larva from a half-grown large narcissus fly larva and indeed from any other fly larva likely to be found in a bulb.

The puparium, in which the adult fly develops, is pear shaped, tough, grey-brown in colour and about ¼ in. (6 mm) long (Plate I). It is found in the bulb, or in the soil nearby.

LIFE HISTORY

Adult flies first appear in the field late in April, and individuals of the successive generations are found until early October. Large numbers of the flies sometimes emerge from boxed bulbs in forcing houses long before they would normally appear in the open but, as with the large narcissus fly, these early arrivals die before they have the opportunity of laying eggs.

Egg-laying starts a few days after the first flies appear in the field. The eggs are deposited in similar positions to those of the large narcissus fly but in batches numbering from 5 to 12 to as many as 30 or 40, never singly. Larvae hatch within three days and immediately move to the nearest bulb, which is generally entered in the neck region where the foliage emerges from the bulb proper. It is here that moist conditions suitable for the small larvae usually occur. Numbers of larvae congregate in the neck to feed in the decayed areas that are invariably present to a greater or lesser extent. These areas are soon enlarged when the larvae move downwards into the bulb itself, which is very rapidly reduced to a pulpy, rotting mass.

A feature of attack by *Eumerus* larvae is that the resulting decay is much more rapid and widespread than that caused by *Merodon*. When the bulb attacked is already unsound, entry may be at any point where decayed tissue is present. The majority of the first brood of larvae develop rapidly and pupate in and around the necks of infested bulbs. In early July second generation adults emerge from these puparia and start egg-laying at once. The majority of larvae produced from these eggs become fully fed in the autumn, remain thus in the bulbs all winter and give rise to the first generation of flies in the following spring. The minority grow very rapidly and produce adults during the current September and October. It is the adults of this partial third generation that are frequently seen on the windows of bulb stores in the early autumn. These autumn flies seldom, if ever, lay eggs. Like those found in forcing houses in early spring, they are only significant in that their presence indicates some other trouble in the bulbs. A few larvae fail to become fully grown before the winter sets in. They feed little during the cold weather, but complete their growth in the spring and emerge as adults in July.

Other Flies Associated with Narcissus Growing

The possibility of confusing *Merodon* with the many hover flies, drone flies and bees has already been mentioned.

The other fly that may be confused with small narcissus flies is another member of the Syrphidae, *Syritta pipiens* (L.) (Plate I). The larvae of *Syritta* live in farmyard manure and decaying vegetable refuse, including remains of bulbs. Neither *Merodon* nor *Eumerus* can breed in these situations, and insects resembling a bulb fly found in such situations are likely to be *Syritta*. The larva of *Syritta* (Plate IV) has three pairs of projections similar to those of *Eumerus*, but the pair next to the central one are simple and not twinned; this character serves definitely to distinguish between the larvae. The puparium can be distinguished by examining the two small projections at the front end; these are pointed in *Eumerus*, while in *Syritta* they are definitely knobbed, like minute drum sticks.

CONTROL OF NARCISSUS FLIES

The large and the small narcissus flies have certain significant similarities in habits:

adults of both kinds first appear about the same time of year;
the eggs are laid in practically identical situations;

but after this various differences arise:

Merodon larvae infest bulbs singly via the baseplate; *Eumerus* larvae are in numbers and enter via the neck;
Merodon is single-brooded; fresh infestations of *Eumerus* can occur at intervals throughout the summer;
Eumerus is almost always a secondary pest, its presence indicating some other pest or disease, while *Merodon* is a primary pest attacking sound, healthy bulbs.

It is against *Merodon* that control measures are mainly directed, though some methods control both pests. Where the large narcissus fly is established, preventive methods are widely adopted as a matter of routine. For convenience the control measures may be grouped under treatment in the field and treatment of the bulbs after lifting.

Control in the Field

In the field many methods have been tried to prevent large narcissus fly attack. After many years of work, attempts to control *Merodon* by killing the adult flies were abandoned because of the poor results obtained. Removal of the foliage, because it attracts the adult flies, was used with success. The normal method of tackling this was to use a rotary hoe to chop up and bury the foliage. This also closed up the crevices left in the soil by the dying foliage and thus prevented the fly from having easy access to the bulb. Earthing up the foliage also helped to reduce the amount of attack.

Covering the beds in May and June with sacking also helped to prevent egg laying but was only feasible on a very small scale or with very valuable stocks and, if done too early, reduced the rate of increase of the bulbs.

In the more windy districts the erection of temporary windbreaks is still practised to reduce wind damage to the flowers. These windbreaks also create situations attractive to *Merodon* for egg-laying. Where windbreaks are needed to protect flowers, they should be removed immediately after the final picking to deprive the large narcissus fly of sheltered areas.

It is an advantage to lift bulbs as soon as they are ready, for the longer they remain in the ground the more liable they are to be attacked.

Control Measures After Lifting and Before Planting

After lifting the bulbs are left in the field to 'ripen'. This exposes them to two dangers, firstly sun-scald and secondly, especially if there is much soil on them, to infestation by small narcissus flies. If bulbs are left in the field in this state they need some form of cover, such as straw, sacking, or even the old dried foliage of the crop.

After lifting, the bulbs should be examined and sorted, and all damaged or obviously affected bulbs destroyed. Destruction should preferably be by burning or by deeply burying them. The detection of fly-infested bulbs is not easy at this stage, but any bulbs that are being lifted will of necessity be treated for eelworm. Most of the control methods for eelworm will also kill any fly larvae in the bulbs. The hot-water treatment (see pp. 29–37) or the thionazin treatment (see page 20) will kill larvae in the bulb. If bulbs are not to be hot-water treated or thionazin dipped, another method which will kill the larvae in the bulb is a cold soak in BHC. This consists of a soak in a solution of 0·05 per cent miscible gamma-BHC for 1 hour with the addition of extra wetter (about 0·1 per cent, depending on the material used). Provided this is done soon after lifting and before the larvae have penetrated too deeply into the bulb, a fair kill can be obtained. But it is emphasized again that any bulbs lifted ought to be hot-water treated, or thionazin dipped, before planting, for the control of stem eelworm and either method will also kill any bulb fly larvae.

Another method of control of bulb fly depends on preventing attack on the bulbs rather than on killing the adults. The treatment can be applied in one of two ways: the bulbs are either dipped in aldrin prior to planting, or aldrin is applied to the soil just before planting (see p. 12). The dip consists of a 0·2 per cent cold solution of aldrin, made by adding one pint of 30 per cent aldrin concentrate to 20 gal water. This strength of dip must not be exceeded, and the bulbs should be soaked in it for 15 minutes.

The 15 minute cold dip should follow the hot-water treatment but, before they are dipped, the bulbs must be allowed to cool down to air temperature. In practice this is done by hot-water treating one day and dipping the bulbs the next. If the bulbs are to be stored after dipping, they must first be allowed to dry; alternatively, they may immediately be planted. All persons handling bulbs wet with insecticide must wear rubber gloves.

It is very important that the hot-water treatment be given before the bulbs have started to root. The danger period starts before roots are showing, when the baseplate has started to swell. Hot-water treatment at this stage of development will cause slight root damage, and the damage will be aggravated if the bulbs are subsequently dipped in aldrin. This will be shown by visibly poor growth in the following one or two seasons and the increase in bulb yield will be below normal for two seasons.

Aldrin can also be applied in the standard hot-water bath. A wettable powder is added to the tank at the rate of 5 lb of 25 per cent wettable powder per 100 gal, and the bulbs are treated for the standard time of three hours at 111–112°F (43·9–44·4°C). While this method has given excellent control under experimental conditions some aspects still need further work and any grower wishing to use this method should seek advice from his N.A.A.S. horticultural adviser.

If the pre-planting dip cannot be used, it is still possible to protect the bulbs by applying aldrin to the soil immediately prior to planting. When bulbs are planted in drills a spraying machine can be mounted on the tractor so that the aldrin is applied immediately after the drill is formed, thus involving no extra labour. It should be noted that loss of insecticide can occur if it remains on the surface of the soil during hot weather; the time elapsing between application and the final closing of the drills needs to be kept to the minimum. The amount of aldrin used for soil treatment should not exceed 3 lb (= 1 gal of 30 per cent aldrin concentrate) per acre.

Summary of Control Measures

The best choice of methods of control will vary from one holding to another and in different parts of the country. A combination of methods may have to be used and those likely to be of most value are as follows:

after lifting all bulbs should be sorted, any soft or damaged ones removed and burned or deeply buried;

bulbs should be either hot-water treated (see pp. 29–37) or thionazin dipped (see p. 20) whenever they are lifted, for control of eelworm. This will ensure that the bulbs contain no live larvae when planted out;

a cold dip in BHC is cheaper than hot-water treatment, but may not kill all larvae in the bulb and does not give adequate protection against subsequent attacks;

a cold dip in aldrin should give complete protection against attack for at least two years;

a soil application of aldrin should give complete protection for at least two years and aldrin can be included in thionazin dips.

Further Reading

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Stem Eelworm and other Eelworms attacking Narcissus

H. G. MORGAN

STEM EELWORM*

By far the most important pest of narcissus in Britain is the stem eelworm (*Ditylenchus dipsaci* (Kühn) Filipjev). Its early history as a narcissus pest is obscure: though the eelworm was known as a pest of other crops in the nineteenth century, it seems to have been unknown to narcissus growers at that period and must have been uncommon even as late as 1910. By the end of the first World War it was well established and threatened the narcissus growing industry with extinction, not only in this country but in Holland and later in America. A paper by Welsford in 1917 showed that even at that time most of the important facts of the biology of the eelworm were known or suspected, and in the following year Ramsbottom laid the foundations for the use of hot-water treatment as a control measure (see p. 29). Although it is no exaggeration to say that this treatment saved the industry from extinction, the victory was incomplete and today few, if any, commercial plantations are free from the pest.

Much research work has been done, but much remains to be done before the pest is completely mastered. At present it constitutes a continuous drain on the capital assets of the industry and adversely affects the prospects of increased sales of bulbs. Knowledge of the biological facts set out in the following sections should enable growers to take reasonable precautions.

IDENTIFICATION OF THE EELWORM

The stem eelworm is a minute elongated colourless worm, less than a tenth of an inch (2 mm) long when fully grown. As the name suggests, it is shaped like a miniature eel. It carries within its mouth a knobbed stylet or 'spear'

*See Advisory Leaflet 460, available from the Ministry (p. 40).

which is used in feeding on plant tissues. It reproduces by means of eggs that hatch into minute larvae similar to the adult.

The above description would also apply to many other species of eelworms, some of them pests but others merely harmless feeders on decaying plant material. It is impossible in a bulletin of this type to give details adequate for definite identification and growers are therefore urged, if they suspect the presence of eelworm in their stocks, to send samples to the nearest N.A.A.S. laboratory or horticultural adviser for specialist examination.

It must be emphasized that this eelworm is very small. It cannot normally be seen in plant tissue with the unaided eye, and even with a powerful pocket lens it is difficult to see. Anything which can be clearly seen with the naked eye *is not a stem eelworm*. This fact is not always realized, and the eelworm is often confused with much larger creatures, such as small soil-inhabiting worms or insect larvae, and, as mentioned above, dead and dying plant tissues may also be invaded by other species of eelworms.

Host Plants and Races of Stem Eelworm

Stem eelworm has been recorded on several hundred species of plants, covering a wide range of families of both crops and weeds. There has been a great deal of confusion, which is still not entirely resolved, on the question of host range. This state of affairs is due to the existence of a number of races or strains of the eelworm, each of which has its own host range. It can be said with certainty that eelworms from most of these hosts are unable to maintain themselves on narcissus to the extent necessary to cause eelworm disease. These differences in behaviour may operate even between quite closely related host plants. For example, one of the commonest races attacks rye, oats and strawberries; it will cause severe damage to onions, but will not attack narcissus. The commonest narcissus race will attack onions but not tulips, while the commonest tulip race can attack narcissus, though it does not always thrive as well as the true narcissus race. The situation is complicated by the fact that different races may interbreed.

Lists have been published of crops and weeds which are capable of harbouring the narcissus race of stem eelworm. Some of these records are the result of artificial inoculation experiments, and in others the identity of the eelworm race is suspect. The lists are certainly incomplete, and no attempt has been made here to include a full list. All that can be said is that weeds constitute a possible source of infestation, and control of all weeds is therefore desirable in the narcissus crop. Crops to be avoided in a close rotation with narcissus bulbs include onions, tulips, snowdrops (*Galanthus spp.*), *Scilla*, bluebells (*Endymion nonscriptus*) and related species, Jacobea lily (*Sprekelia formosissima*) and *Gladiolus*.

Symptoms of eelworm attack, depending upon the host, may appear on some of the alternative hosts, but in many cases eelworm may be present—as indeed it may be present on narcissus—without any visible symptoms. If there is circumstantial evidence that a particular plant may be acting as a carrier of the eelworm, this can only be confirmed by laboratory examination.

Life History of the Eelworm

The life history of the eelworm is very simple. Male and female eelworms live in the plant tissue and produce eggs which hatch into small larvae. These feed and grow, casting their skins at intervals. There are four larval stages, the fourth-stage larvae becoming fully-developed adults at their final moult. The pre-adult fourth-stage larva is very important in the biology of the eelworm, for it is involved in the production of 'eelworm wool'. If the bulb tissues become too dry, too rotten or too overcrowded, they become unsuitable for continued reproduction of the eelworms. Many will die within the tissues but under these conditions the fourth-stage larvae migrate out of the inhospitable tissue, either to the outside of the bulb or to an air-space between the scales or in the neck region. Here they curl up into close spirals like watch-springs and lose most of their body moisture. It is the tangled mass of coiled larvae which forms the white masses known as 'wool'. This may remain in the dry condition for many years, and when it is wetted the dried eelworms absorb moisture and return to active life.

While in the 'wool' stage, eelworms are easily spread by handling, or even by air movements. They are also very resistant to hot-water treatment until they have been reactivated by soaking. One of the most important points in successful eelworm control is to manage the stocks so as to reduce 'wool' formation to a minimum, and in particular to hot-water treat only stocks in which the amount of 'wool' has been kept very low by suitable storage, sorting and if necessary pre-soaking (see p. 32).

Symptoms of Attack

Stem eelworm attack in narcissus has sometimes been called 'ring disease', because the most characteristic and best known symptom is the presence of rings of dead and dying tissue which are seen when the bulb is cut across (Plate VI). The rings can be seen both in the dry bulb and during the growing season, and with the multiplication of the eelworms the area of damaged tissue spreads rapidly until the whole bulb is rotten. An attacked bulb is sure to die unless the eelworm is controlled by hot-water or chemical treatment (see pp. 19–21). If untreated bulbs are left in the ground they rot, releasing eelworms which move through the soil and infest fresh hosts.

The first symptoms of eelworm attack to appear in the field are swellings, often pale in colour, on the leaves and stems, which are known as spickels (see Plate II). One or two eelworms, entering in the neck region, cause the tissues to swell and they then live and breed in the swellings. At a later stage of growth the spickels may spread and coalesce, distorting the leaf, which ultimately rots.

In more severe attacks, when the bulb itself is already heavily infested with eelworms, the developing foliage is yellow, dwarfed, lumpy and distorted. The flower stems may be shortened and twisted; flowering is often delayed, and in extreme cases it may be completely prevented. These symptoms appear very strongly, and often with dramatic suddenness, in stocks grown under forcing conditions. In these circumstances eelworms multiply much more rapidly than they do outside, and apparently clean stocks may break down completely in a matter of a few weeks.

In the first year of growth of an infested stock on clean land, infested plants are scattered at random through the crop. Adjacent plants become infested during the first season of growth, so that in the second year damage appears in patches. The centre of the patch is bare, all the bulbs having been killed, and is surrounded by an area of severely attacked bulbs, outside which is a ring of bulbs with only slight symptoms. A similar patch effect is seen when stocks are planted on land which is already infested, but in this case the gradation from dead bulbs to unaffected is not so clearly marked. In dry bulbs, the presence of eelworm in a stock is shown by the presence of abnormally soft bulbs, which show the characteristic brown rings when cut. Infested bulbs deteriorate rapidly in store, losing both weight and condition. They may be attacked by small narcissus fly (see p. 8), by bulb mites (see p. 27) and by various bacteria and fungi which cause rotting that may lead to invasion by scavenging insects and worms.

Patterns of Attack and Spread

Eelworm infestation almost always arises from the planting of an infested stock of bulbs.

Eelworms multiply within the attacked bulbs, later leaving them and spreading to adjacent plants. When the stock is lifted, unless steps are taken to control the eelworm attack, these newly attacked bulbs will be distributed through the stock, which will deteriorate at an ever-increasing rate.

The second major pattern of attack arises from planting in infested land. In most cases the infestation arises from groundkeeper bulbs from a previous infested crop, though weeds may also play a part. It is possible for infestation to arise directly from eelworms remaining in the soil; estimates vary of the length of time during which this is possible, but in normal soil conditions the eelworm is very unlikely to remain alive in soil, in the absence of a host-plant, for more than 18 to 20 months. Attacks on infested land will tend to show a pattern of patchy attack from the very first, and the subsequent development of the attack will be the same as that from infested stocks.

Eelworm may also be spread during the handling of the stocks between lifting and planting. Clean stocks may become infested if they are passed through unsterilized trays or grading machinery which has previously been used for handling infested stocks.

Insecticidal or fungicidal dips (e.g., against narcissus fly or basal rot) may spread eelworm infestation from one stock to another unless they incorporate a nematicidal material, or unless the dip is discarded and replaced with a clean batch after treating suspected bulbs.

Field Precautions and Inspection of Stocks

The most important step in the reduction of eelworm attack on the holding is regular inspection of the growing crop in the field. Inspection starts at the stage when the plants are beginning to show through the soil; when the majority of the foliage is about 6 in. (15 cm) high, it is easy to detect patches of stunted growth. If the growth is uneven, closer attention is warranted, and the ideal inspection method is to walk along every sixth or eighth row, carefully examining the adjacent rows and taking a general view of the three or four rows on either side. Canes or other markers should be used to mark suspect plants or areas. At this stage there are three main symptoms to look for:

gaps where plants have failed to emerge,
stunted and distorted growth,
the presence of spickels on the leaves.

If an eelworm attack is detected at this stage, all obviously affected plants should be dug out and destroyed, together with adjacent plants, even if these are apparently unaffected. It may also be worth treating the soil as described on p. 19. Heavy injections of D-D* (at the rate of 600–800 lb per acre or even more) should kill both bulbs and eelworms in the ground. This saves the labour of digging out the infested bulbs and reduces the risk of spreading eelworm to clean stocks while the infested material is being carried away.

A further inspection just before flower-picking starts is a wise precaution. Much avoidable spread of eelworm occurs at picking time. If eelworm is confined to definite patches in the field, these can be marked off and pickers instructed not to enter them. It may be impossible to avoid picking in infested areas, and in this case the dangers can be minimized by planning the order of picking so that pickers do not move from infested stocks to clean ones. Nematicidal dips may be placed at field gates so that staff leaving the infested area can disinfest their footwear.

A final inspection should be carried out after picking has finished, and before the foliage dies down. The decision whether to lift and treat the crop will depend on the results of this inspection. Ideally, any infested crop should be lifted and treated. Even a light infestation during the first year of a crop can lead to reduced flowering and serious loss of bulb yield in the second year. This, in its turn, increases the risk of further spread of infestation to clean stocks, and successful control of eelworm in the infested stock itself will be more difficult. Leaving an infested crop down for a second year must be a calculated risk, and should be avoided.

The final decision on treatment of an infested stock must always depend on the value of the stock. Expensive varieties, and those which give a good financial return for flowers, will always repay the trouble and expense of eelworm control. Many infested stocks, however, are of outdated varieties; flower prices may be uneconomic and, in any case, the replacement cost of the stocks will be low. In such cases the best course is often to lift and destroy the stock as soon as the last flowers have been picked. This will minimize the danger of spread of eelworm and avoid the cost of a possibly ineffective eelworm control. The stock can be replaced by new stock from a clean source and, preferably, of a better variety.

Avoidance of Attack

Eelworm attacks arise from two main sources, the stock of bulbs and the land, and to a lesser extent from the spread of infested material on the holding. When a bulb-growing enterprise is started in a new area, the two latter causes are insignificant, and most attacks can be traced to the introduction of infested stocks. Bulbs from reputable sources will usually be reliable, but even the best holdings are affected by eelworm to some extent and apparently healthy bulbs, lifted from fields with no apparent symptoms, may carry sufficient eelworms to start an attack.

When new stocks are purchased, they should be treated against eelworm before planting, either by hot-water treatment or by a chemical dip, if this is at all possible. New stocks, whether treated or not, should be regarded as being in quarantine for the first year of growth. They should not be mixed

*Dichloropropane-dichloropropene mixture. (Technical dichloropropene is also available and is equally suitable.)

with clean stocks of the same variety until their health is established. If possible, new stocks should be planted in isolation and kept under close observation throughout the season. After one or two years' satisfactory growth, they may be lifted, treated and then brought into the normal routine of the holding.

If eelworm is already present on the holding, the utmost effort is necessary to restrict its spread. Much spread in the past has been caused by cultivations, though with the increasing use of herbicides there is less necessity for machinery to work in bulb fields while the foliage is growing. If for any reason cultivations must be carried out, they should be so arranged that work starts on uninfested land, finishing in the infested area. When the machinery leaves the infested area, it should be cleaned off, either with high-pressure water jets or by the use of a liquid nematicide (details of suitable materials can be obtained from the local N.A.A.S. horticultural adviser). Care must be taken that the washing water is safely disposed of and not allowed to flow where it may carry eelworms on to bulb fields, or into streams or dykes.

Storage trays and bags which have been used for infested stocks must also be sterilized before re-use, and care must be taken in the choice of standing ground. If bulbs are lifted from infested parts of a field, they should not be stood on the clean parts of the field which are to remain unlifted, nor on ground which is to be replanted with bulbs. Clean stocks should not be stood on infested ground.

CONTROL METHODS

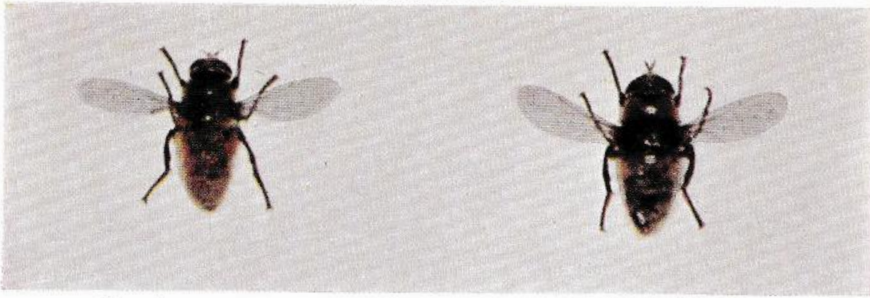
Control by Rotation

Careful planning of rotations involves little or no expense but plays a very important part in the limitation and control of eelworm infestations. If, as on some small specialized holdings, bulbs occupy the major proportion of the land, true rotation is impossible, but where sufficient suitable land is available, rotations should be planned so that bulbs are not replanted in land that carried bulbs less than two years before. Where a crop is known to have been infested, the break should be at least four years.

Since eelworms will not normally survive in soil for more than about 18 months without a host plant, it is in theory possible to starve out an attack within two years. This can only be done if no hosts are present, and implies the removal or destruction of all groundkeeper bulbs, and the control by herbicides of all potential weed hosts. Work is in progress on the chemical destruction of groundkeepers, but no fully reliable method has yet been discovered; at present the soundest method, though expensive in labour, is hand-digging of groundkeepers from among the succeeding crop.

The crops grown in the break between successive bulb crops must not, of course, be hosts of the narcissus race of stem eelworm, and fortunately there is quite a wide choice of cropping. Potatoes, lettuce and most non-bulbous flower crops (including anemones) are safe, as far as is known. Although the narcissus eelworm has been shown in laboratory tests to multiply well in brassicas, there is no field evidence that winter cauliflowers or spring cabbage are unsafe in a bulb rotation. Grass leys are also safe as long as their management does not interfere with the detection and removal of groundkeeper bulbs.

Plate I:
NARCISSUS FLIES



Female
Large narcissus fly

Male
Large narcissus fly

Puparium of large
narcissus fly

Small narcissus fly

Syritta pipiens

Opened puparium of
small narcissus fly

(all slightly enlarged)

PLATE II:

STEM EELWORM

Middle leaf showing spickels caused by stem eelworm

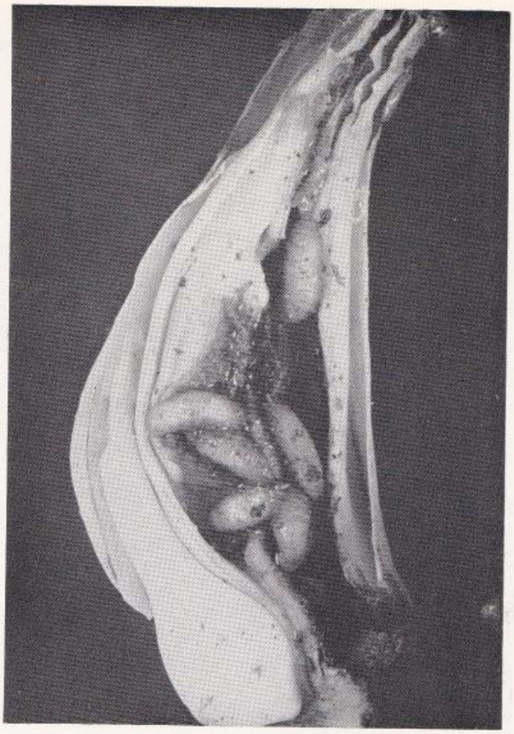
Plants damaged by stem eelworm

Left: slightly infested

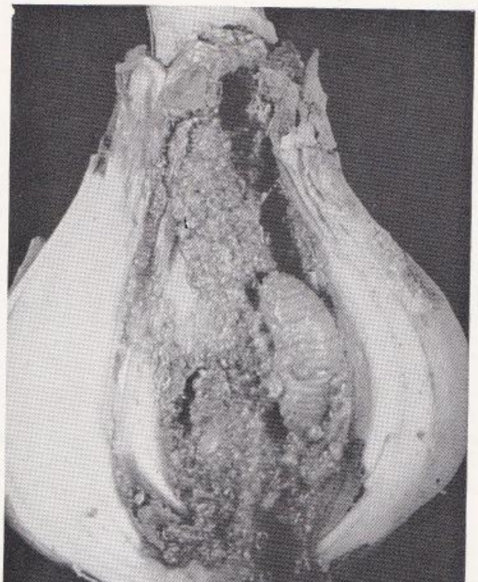
Right: severely infested

PLATE III:
NARCISSUS FLIES

Eggs of small narcissus fly on dried foliage (enlarged)

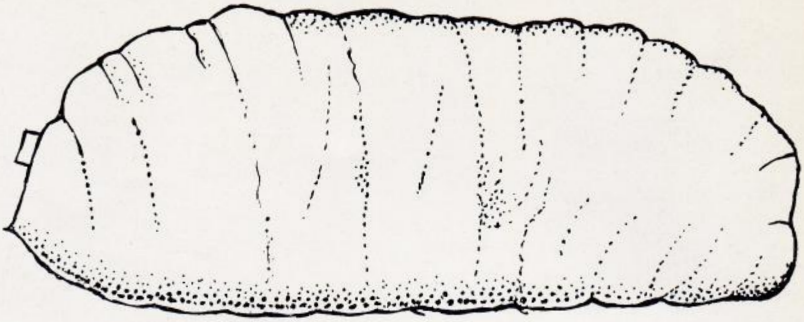


Larvae of small narcissus fly in bulb (slightly enlarged)

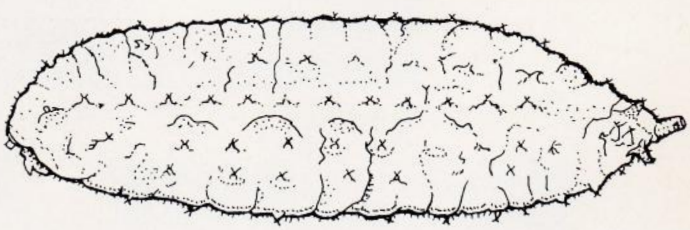


Larva of large narcissus fly in bulb (slightly enlarged)

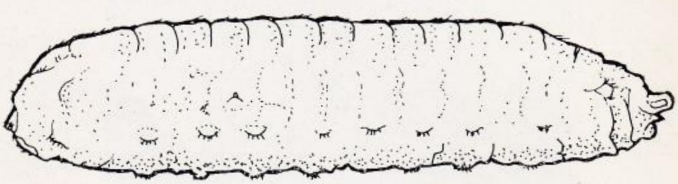
Plate IV:
NARCISSUS FLIES



Larva of large narcissus fly (enlarged)



Larva of small narcissus fly (enlarged)



Larva of *Syritta pipiens* (enlarged)

PLATE V:

STEM EELWORM

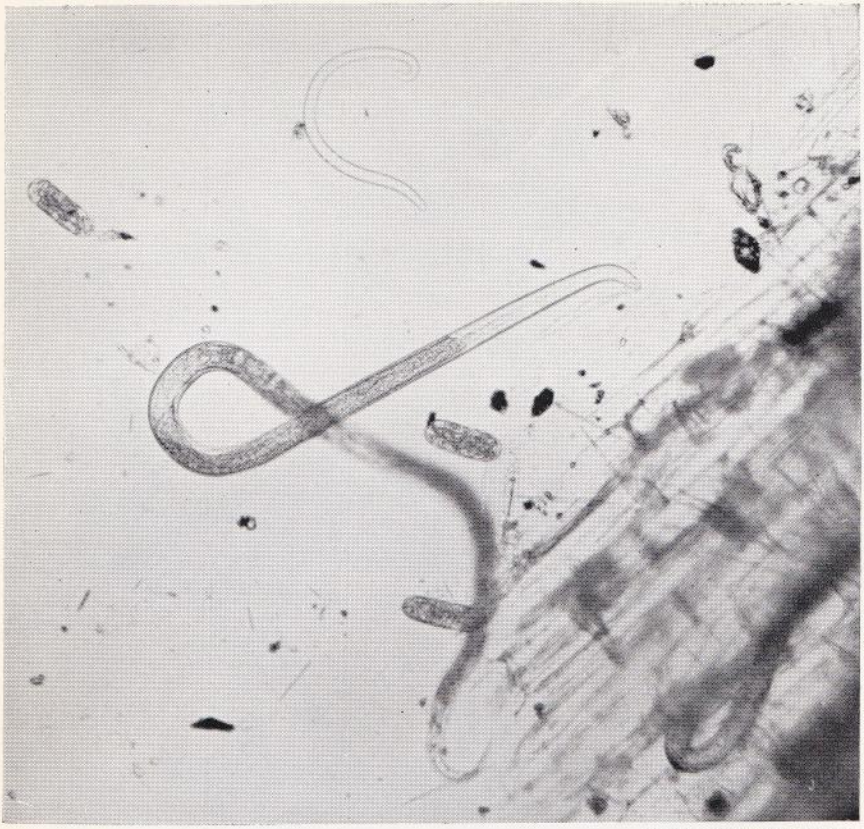
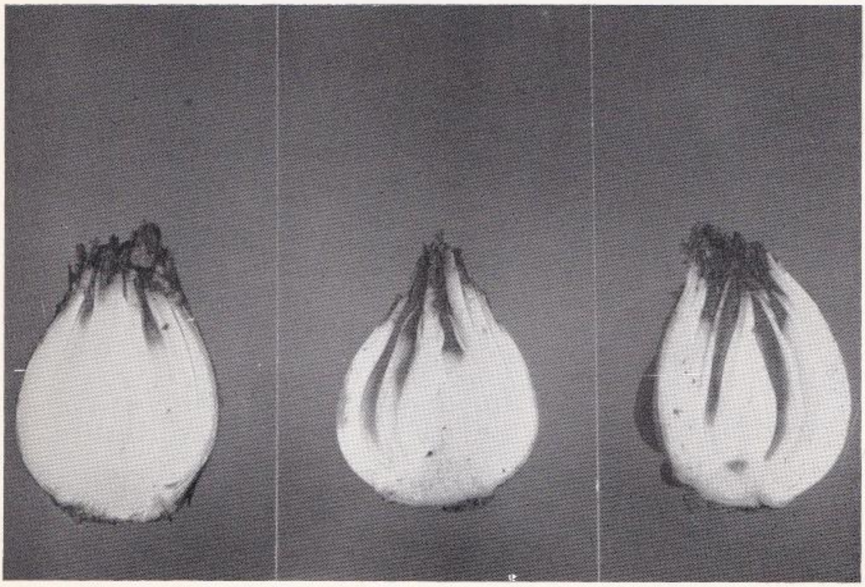


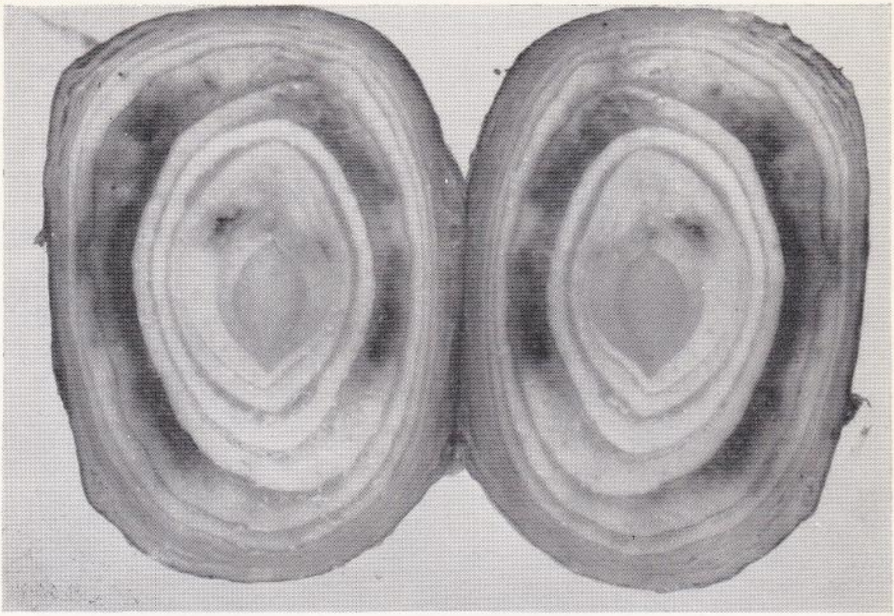
Photo: C. C. Doncaster

Electronic-flash photomicrograph of live adult eelworm, eggs and young larva from infested narcissus leaf. Note adult embedded in leaf-tissue, lower right corner (much enlarged)

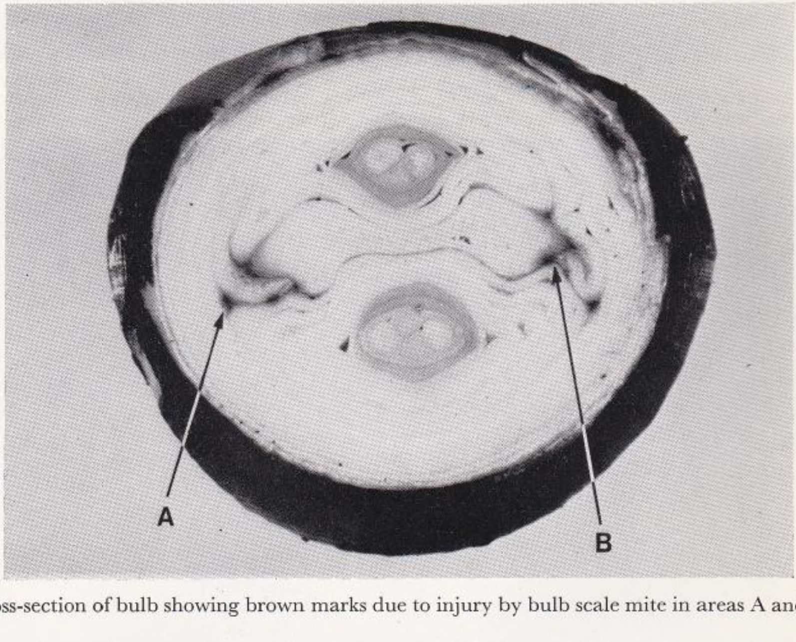


Stem eelworm; vertical sections of bulbs showing infestation extending down from the neck

Plate VI:
STEM EELWORM AND BULB SCALE MITE



Cross-section of bulb showing brown ring effect due to stem eelworm



Cross-section of bulb showing brown marks due to injury by bulb scale mite in areas A and B

PLATE VII:
BULB SCALE MITE

Forced narcissus (var. *Scarlet Elegance*) showing severe bulb scale mite damage

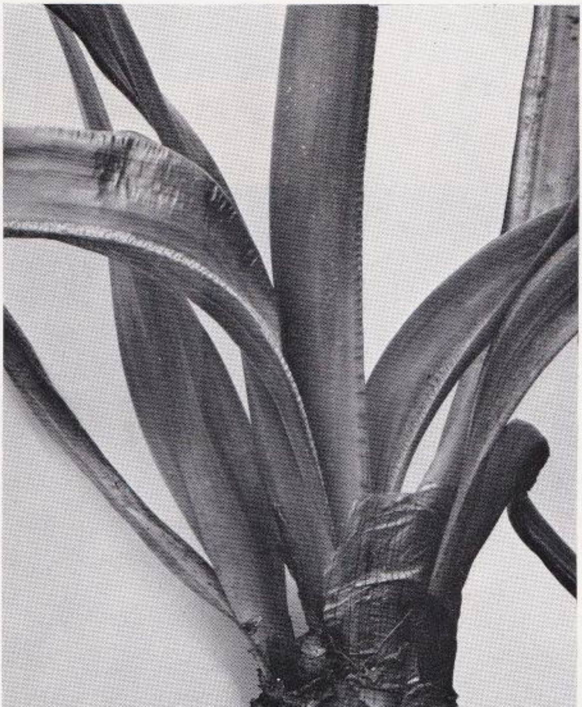
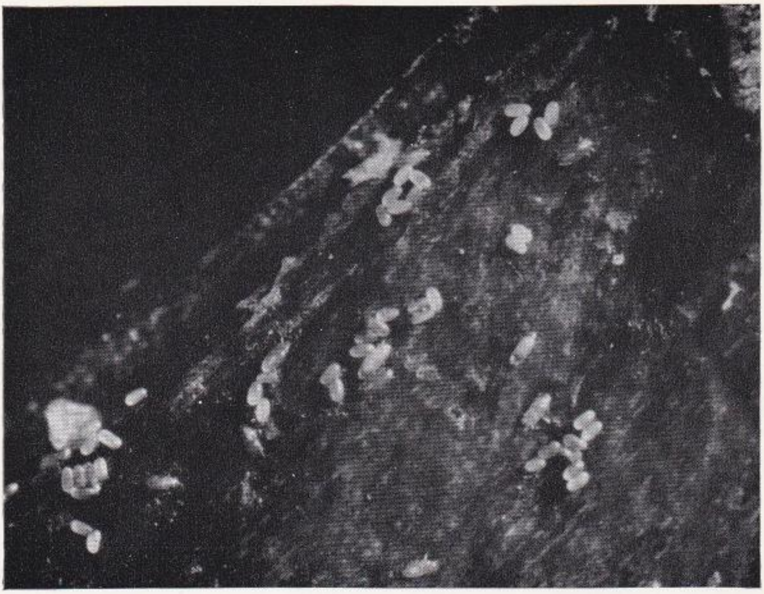


Photo: Glasshouse Crops Research Institute

Damage to narcissus leaves and flower stem caused by bulb scale mite. Note scars on distorted leaves and 'saw-edge' to flower stem

PLATE VIII:
BULB SCALE MITE AND BULB MITES



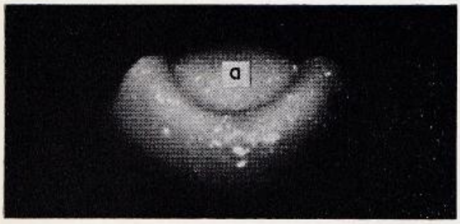
Adults and eggs of bulb scale mite on bulb scale (much enlarged)

Adult and young bulb mites (much enlarged)

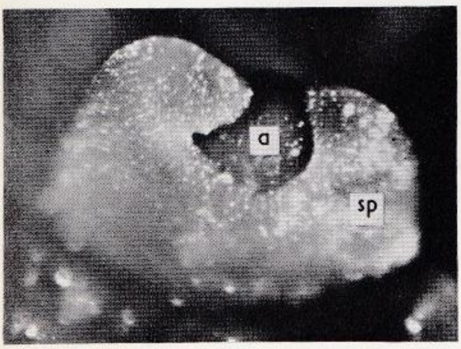
Plate IX:

GROWTH STAGES OF THE NARCISSUS FLOWER WITHIN THE BULB

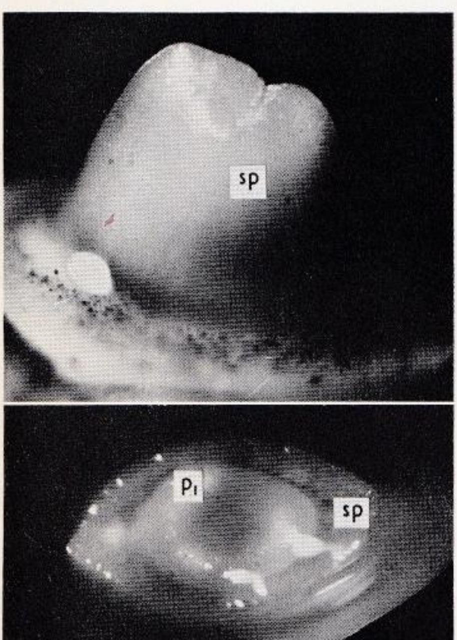
(from Preece and Morrison, 1963)



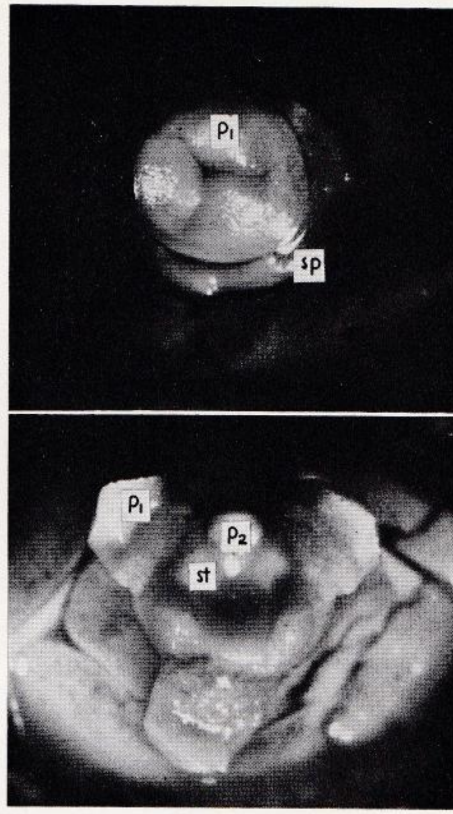
II Apex of undifferentiated flower initial ($\times$30) (Early May)



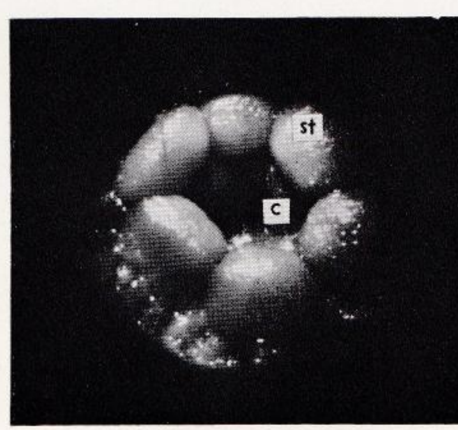
Sp. Asymmetric initial of spathe about flower apex ($\times$30) (Mid May)



P_1 *Above:* before removal of spathe.
Below: after removal of spathe showing initials of three outer petals ($\times$25) (Late May).



A_1— *Above:* with outer petals in place
Below: with outer petals broken open, showing inner petal and outer stamen initials ($\times$25) (Late May)

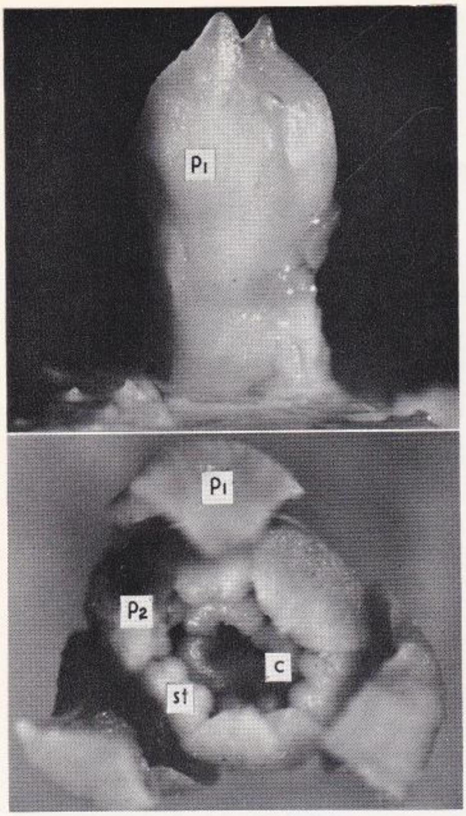


A_2+ with petals removed, showing six stamens. Carpels just visible ($\times$ 35) (Mid June)

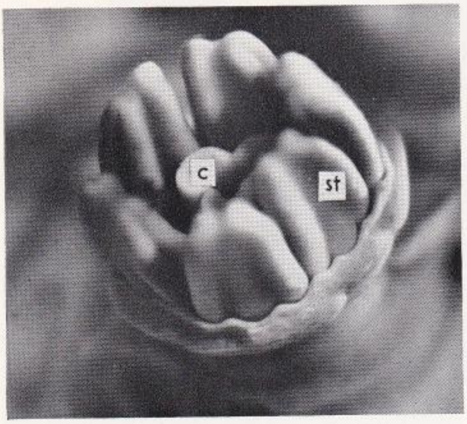
PLATE X:

GROWTH STAGES OF THE NARCISSUS FLOWER WITHIN THE BULB

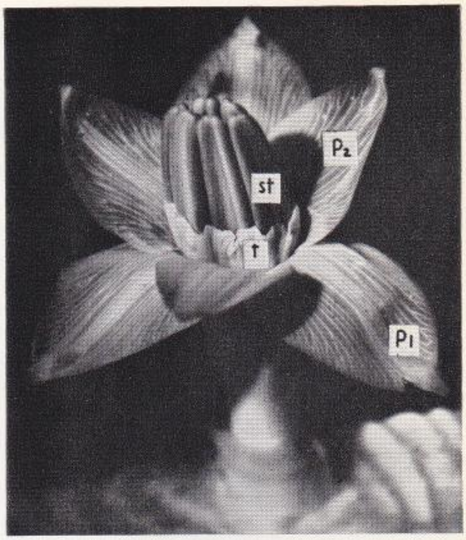
(from Preece and Morrison, 1963)



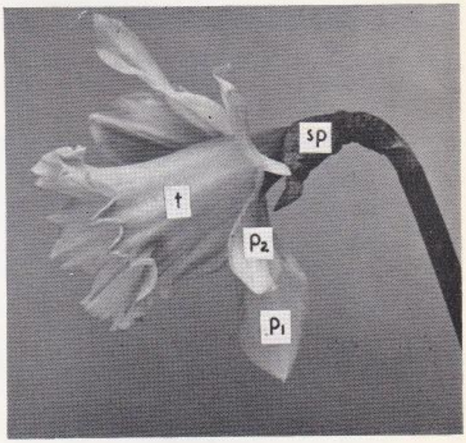
G+ *Above:* side view, spathe removed (×12). *Below:* with petals forced open, showing stamen and carpel initials (×25) (Early July).



Pc with petals cut away, showing trumpet initials, stamens and carpels (×15) (Late July).



Pc+ Petals forced open, showing stamens and trumpet (×10) (Late September).



Mature Flower (×½)

a = apex of flower initial
sp = spathe
p_1 = outer petals
p_2 = inner petals
st = stamens
c = carpels
t = trumpet

Plus (+) or minus (−) signs after the stage symbols indicate intermediate stages.

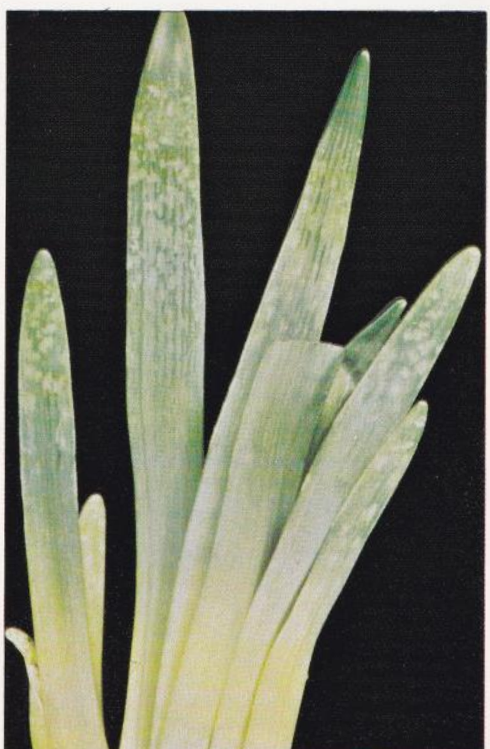
Dates given are for King Alfred grown in the open at Harpenden.

HOT-WATER TREATMENT

A

B

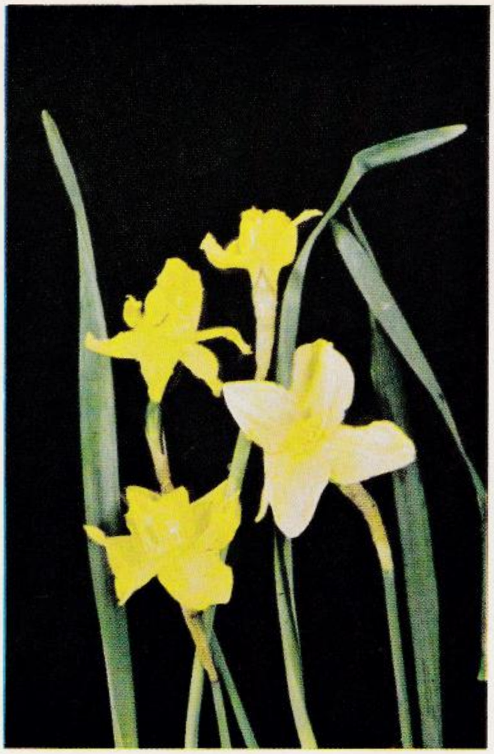
Damage to flowers caused by hot-water treatment. A: normal flowers; B: stunted and distorted flowers (split flower condition) after too-early treatment



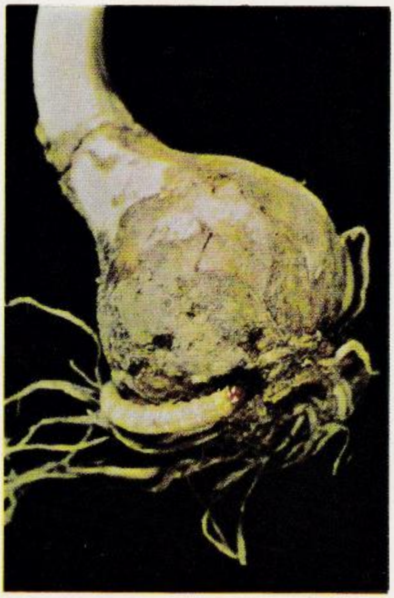
Spotting on leaves towards the tips caused by too-late treatment

Plate XII:

SLUGS AND SWIFT MOTH



Slug damage to narcissus flowers. Note the shortening and holing of trumpets, and 'rasping' of petals



Garden swift moth caterpillar attacking narcissus bulb

Where rotation is impracticable, the safest practice is to keep the bulbs in the ground for as short a time as possible, by late planting and early lifting. Under these circumstances it is advisable to leave the crop down for one year only, even at the expense of some loss of flower crop. If stocks are left on infested land for two years, a reduction of bulb yield by as much as 50 per cent could result, and the long-term loss of flowers and bulbs may be expected to outweigh any apparent short-term gain in flower pick.

If the area of clean land available is insufficient to allow of adequate rotation, it may be necessary to resort to chemical treatment of the soil (see next section). Though expensive, this is in many cases the only practicable alternative to moving the enterprise to land which has never grown bulbs.

Control by Soil Injection

Various chemical treatments are capable of destroying eelworms in the soil. Some of these have not yet been shown to be fully effective under field conditions; others are ruled out on grounds of expense or because they are too dangerous to the operator. At present the only method which can be advised is the injection of D-D mixture. (See also footnote on p. 17.) This is a liquid which is injected into the soil six weeks or more before planting, either with a hand injector or on the larger scale by a tractor-mounted injector. The normal rate of application for eelworm control is 400 lb per acre, and the effectiveness of the treatment can be increased by a surface seal with a suitable nematicide watered on to the soil surface at about 2 gal per sq. yd. after injection. Further details of the method, and advice on suitable injectors can be obtained from N.A.A.S. horticultural advisers.

Where small infested patches are detected in the growing crop, D-D may be used to destroy the bulbs and eelworms in the ground. For this purpose a hand injector should be used. The spike of the injector is pressed into the neck of the bulb, with the depth gauge adjusted so that the fumigant is ejected at about the level of the bulb, and two strokes given on the pump. This is repeated for each infested bulb and for a ring of apparently healthy bulbs around the patch. If the bulbs are widely spaced, single injections should also be made at intervals of about 9 in. (23 cm) between them.

Control by Hot-water Treatment

The subject of hot-water treatment is fully covered on pp. 29–37 and all that is necessary, at this point, is to relate it to the overall programme of control measures. Until it is superseded by improved chemical methods (see p. 20), hot-water treatment will remain the major item in eelworm control but its effectiveness will be reduced unless it is supported by a full programme for the detection, control and limitation of spread of eelworm attack.

Inspection in the field will show which stocks are most in need of treatment, and roguing out or killing infested plants in the field will eliminate most of the very heavily infested bulbs which are often responsible for partial failures of hot-water treatment. When the stocks that need treatment have been detected, they should be given priority of treatment. They should be lifted as soon as the condition of the foliage allows, and given hot-water treatment early, regardless of the stage of development of the flowers. It is false economy to attempt to save the flowers in the first year by delaying treatment.

In store, the bulbs should not be allowed to dry out, as this encourages the formation of eelworm 'wool'. They should be cleaned as soon as possible, and all soft bulbs removed and destroyed. Unless known to be only very lightly infested, stocks with eelworm should never be given pre-warming or pre-cooling treatment; in either case there is a danger of contaminating the store with eelworms, and pre-warming has been shown to reduce the effectiveness of eelworm control by subsequent hot-water treatment. If the bulbs have become dry, they may be pre-soaked.

It must also be remembered that hot-water treatment will only kill eelworms present in the bulbs and gives no protection against reinfestation. After treatment, the bulbs must be handled in eelworm-free conditions and replanted in clean ground, or the object of the treatment will be defeated.

Control by Chemical Dips

A. L. Winfield

The systemic organophosphorus nematicide thionazin has recently been introduced in Britain for stem eelworm control. When bulbs are dipped in thionazin, it is absorbed by the healthy tissues, which become poisonous. Eelworms feeding on this living tissue take in a lethal dose of the nematicide. Dead tissue will not absorb the chemical, and any eelworms in this will be unaffected. Apparently the chemical can also kill eelworms by prolonged contact but most are killed after they have consumed plant tissues that have absorbed the poison.

After lifting and cleaning, bulbs should be immersed for two and a half hours in a cool (about 65°F (18°C)) solution of 0·23 per cent thionazin. The dip is prepared from the commercial 46 per cent concentrate at the rate of 4 pints per 100 gal water. For topping up, 2 pints of concentrate are added for every 25 gal of water added. The chemical deteriorates in the bath, especially if it is dirty, but it is not yet known for how long a dip can be used before it must be completely replaced. The solution should be continuously agitated during treatment, preferably by the use of a circulating pump. Other materials may be added to the bath for bulb fly and disease control; thionazin is compatible with formaldehyde, mercurial fungicides, aldrin and most wetters, but the manufacturers' instructions for use should always be followed carefully. As yet, there have been few reports of phytotoxicity following the use of thionazin, but it is possible that some varieties are more sensitive than others.

Thionazin offers an attractive alternative to hot-water treatment for stocks intended for flower production. There have been no reports of flower damage caused by thionazin dips, though slight shortening of the flower stems has been noted. Stocks of bulbs intended for bulb production may also be treated with thionazin, *provided that they have no more than a light infestation of stem eelworm.* If there is any considerable amount of dead tissue due to eelworm or any other cause in the bulbs, eelworm control will not be effective. All soft bulbs *must* therefore be removed before dipping.

Thionazin has not been in use sufficiently long to allow a full assessment of its capabilities. However, it is already clear that, while it may be used as a precautionary measure on seemingly healthy stocks, it is inferior to hot-water treatment on obviously infested stocks.

Growers should consult their local N.A.A.S horticultural adviser about treatment and for the latest information.

Thionazin is in the Second Schedule of the Agriculture (Poisonous Substances) Regulations as a Part II substance. Great care should therefore be taken when using it and when handling the treated bulbs (see also under Precautions, p. 40).

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OTHER EELWORMS OF IMPORTANCE TO THE NARCISSUS CROP

H. G. MORGAN

ROOT-LESION EELWORMS

Root-lesion eelworms (*Pratylenchus* spp.) are similar in appearance to the stem eelworm but attack only the roots of plants, which are not entered by stem eelworms. They are responsible for 'root-rot' that can cause considerable losses in narcissus crops. They are usually associated in narcissus with a fungus, *Cylindrocarpon radicicola*, but it is now known that the eelworm is the primary pest and the fungus only secondary, though the adverse effect on plant growth is probably mainly due to the fungus. Rotting of the roots can occur in the absence of *Pratylenchus*, but little is known of other causes of the condition.

There are several species of root-lesion eelworms, which between them have a very wide host range. Among the recorded host crops in Britain are cereals, potatoes, spinach, strawberries, onions and a range of Ranunculaceae (*Anemone*, *Clematis*, *Delphinium*, *Helleborus*, *Ranunculus* and *Thalictrum*), but this list is by no means exhaustive and it is not known in all cases which species is responsible. In addition to *Pratylenchus* itself, there is a complex of soil-inhabiting eelworms of several genera, such as *Hoplolaimus*, which can damage roots by feeding from outside without entering and breeding in them. These may be involved in the decline of bulb stocks, and it is hoped that further investigations will clarify the position of the various eelworms in relation to different host plants.

Attacks by *Pratylenchus* have been severe in the Isles of Scilly in recent years and cases have also been reported from south-west England and from Lincolnshire. Damage is first seen in early March, when attacked plants begin to lag behind the rest of the crop in their growth. Within a few weeks distinct patches of retarded plants can be seen in the affected area. Apart from the retarded growth, there are no symptoms on the foliage of narcissus, though it has been reported from Germany that other plants, notably lily-of-the-valley, show a yellowing of the foliage when severely attacked. When the retarded plants are lifted, it is found that the roots are brown, rotting and usually broken off short. Laboratory examination at this time may show the presence of eelworms in the roots, though the best time for examination is earlier in the season, before rotting starts. At this stage, small black slit-like lesions may be found on the roots, each containing a small group of eelworms and their eggs.

The eelworm is confined to the roots and is very susceptible to desiccation and thus there is no danger of its being carried to fresh land by the planting of bulbs from even a severely attacked crop. In any case, hot-water treatment would kill any eelworms surviving in the remains of the roots.

Control measures must be directed against the eelworm in the soil. As with the stem eelworm (see p. 19) the most satisfactory material is D-D mixture, applied at the rate of 400 lb. per acre. This gives a marked improvement in the growth of bulbs planted after treatment, though part of the increased vigour is due to a 'soil amendment' effect and control of the eelworm is never complete. There is likely to be a slow decline of crops left down for many years after soil treatment, but the effects are seldom serious on a two- or three-year crop.

Biological control measures are also a possibility. It has been shown that certain plants, notably the African Marigold (*Tagetes erecta*), produce secretions which can suppress the growth of *Pratylenchus* populations. Some benefit to a following bulb crop has been obtained by growing *Tagetes* and cultivating the residues of the crop into the soil before the bulbs are planted.

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Narcissus Bulb and Leaf Eelworm*

This eelworm is comparatively rare. In the British Isles it was first found in bulbs from the Isles of Scilly in 1934, and although it can cause serious damage, attacks appear to be very infrequent.

It is slightly smaller than the stem eelworm and, as with other eelworms, laboratory examination is necessary to confirm its identity.

Bulbs attacked by this eelworm show a blistering and crinkling of the outer scales in contrast with the smooth surface of a healthy bulb. If the attacked bulb is cut across a rather diffuse, greyish discoloration is seen, unlike the more distinct, concentric rings that are associated with stem eelworm attack. During the growing season the leaves become heavily infested and turn yellowish in colour, with a tendency to die down prematurely. Spickels are not formed and there is no destruction such as is caused by the stem eelworm.

The infestation does not seem to spread rapidly in a stock. So far, it has only been reported from Cornwall and the Isles of Scilly, where it was found both in bulbs and associated with root samples.

Control should easily be obtained by means of a suitable crop rotation and by hot-water treatment of the dry bulbs (see p. 29). Once established on a holding it would appear to be a danger only if bulbs are lifted infrequently and are grown too often in the same piece of land. Although there have been no reports of its presence in recent years, it should be watched for, as it might well become a serious pest if allowed to spread.

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Eelworms as Vectors of Viruses Affecting Narcissus

J. F. Southey

In 1958 a soil-inhabiting eelworm of the genus *Xiphinema* was shown to transmit a virus disease of grape vines; this was a hitherto unknown role for eelworms. The discovery stimulated a search for more eelworm vectors and

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* *Aphelenchoides subtenuis* (Cobb) Steiner and Buhrer

fresh interest in the group to which *Xiphinema* belongs. Three groups of root-feeding eelworms are now known to be vectors of plant viruses and all three have been found around the roots of narcissus bulbs, chiefly in south-west England and the Isles of Scilly. Surveys of British narcissus stocks have revealed that eleven different viruses occur in them and multiple infections are common. Five of these viruses are eelworm-transmitted in other host plants but it is not yet known what part eelworm vectors play in the spread of viruses in narcissus. Clearly much spread must be by vegetative propagation, but the eelworms could be the means of introducing infection to fresh stocks. The following table summarizes the virus-eelworm relationships:

Viruses Transmitted	*Eelworm Group*
arabis mosaic (AMV) strawberry latent ringspot (SLRV)	*Xiphinema* (dagger eelworms)
tomato black ring (TBRV) raspberry ringspot (RRV)	*Longidorus* (needle eelworms)
tobacco rattle (TRV)	*Trichodorus* (stubby-root eelworms)

These viruses are frequently almost symptomless in narcissus, but tobacco rattle is an exception. It is the most damaging of them and in trumpet daffodils is now known to cause the disease described as 'mottle'. RRV has so far been isolated only from Scottish narcissus stocks. The occurrence of multiple virus infections understandably makes diagnosis difficult. Experience with control of arabis mosaic in strawberry and preliminary tests with narcissus in the Isles of Scilly suggest the possibility of preventing infection of valuable narcissus stocks by soil fumigation with D-D.

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Mites attacking Narcissus

A. L. Winfield

BULB SCALE MITE*

The bulb scale mite (*Steneotarsonemus laticeps* (Halb.)) is a major pest of narcissus in this country. It is a member of the family Tarsonemidae to which belong several economically important species, for example the strawberry mite, *S. pallidus*, which attacks strawberries outdoors and begonias and cyclamen under glass, the fern mite, *Hemitarsonemus tepidariorum*, which is injurious to ornamental ferns, and *Acarapis woodi*, the mite that causes acarine disease in hive bees.

Bulb scale mite was first described from narcissus bulbs in Ireland in 1923. Since then it has been found almost everywhere in the world where nar-

*See also Advisory Leaflet 456, available from the Ministry (p. 40).

cissus is cultivated. It is probably a specific pest of narcissus and there are no known alternative host plants.

IDENTIFICATION

The adult bulb scale mite is extremely small, approximately $\frac{1}{125}$ in. (0·2 mm) long, and should not easily be confused with the very much larger bulb mites which are described on p. 28. The body is elongate, colourless to pale brown and semi-transparent. There are four pairs of legs, the hindmost pair in the female are modified and resemble stout bristles forked terminally, while the corresponding pair in the male are developed into thick curved, claw-like claspers. The larval stages closely resemble the adult, except that they have three pairs of legs instead of four and they are, of course, smaller. The eggs are large in relation to the size of the parent mites and they are oval, smooth and pearly-white in colour (Plate VIII).

LIFE HISTORY

The mites live between the fleshy scales within the bulb and feed by piercing and scarifying the scale surfaces. They tend to congregate in longitudinal strips running down from the neck to the baseplate of the bulb and they are most numerous and breed most freely in the small folds and creases in the scales. There are several overlapping generations during the year.

The mites are less active in the colder months but in spring, or earlier, when bulbs are brought into a glasshouse for forcing, they can breed very rapidly. As the bulbs become overcrowded many mites migrate upwards, feeding and laying eggs on the young foliage for some distance above the bulb itself, although mites and eggs are still most numerous near the necks of the bulbs. It is at this stage in the attack that mites move on to healthy bulbs nearby. In cool damp seasons acute attacks are not experienced outdoors; only under warm dry conditions do the mite populations reach epidemic proportions. Nevertheless, even under unfavourable weather conditions, the constant presence of numerous mites within the bulbs has a depressing effect upon both vigour and performance.

Another point about the life history is worth noting here. For most of the year the mites live between the fleshy bulb scales which often have large air spaces between them, particularly during the flowering period. These spaces are caused by shrinkage of the scale during the outflow of stored nutrients from the bulb into the vigorous top growth of foliage and flower. The spaces become filled with mites which keep the bulb in poor condition throughout the autumn and winter. In early spring, when root action begins again, the mites are relatively inactive, and as the bulb scales swell up large numbers are crushed to death. This swelling effect is most marked in well-shaped and round bulbs but is negligible in damaged and ill-formed bulbs in which few mites are killed. When selecting bulbs for forcing it is, therefore, worthwhile to select only solid, symmetrical bulbs, for to attempt to force bulbs containing large numbers of living bulb scale mites invites almost certain failure.

Symptoms of Attack

IN THE LIFTED BULB

If bulbs are undersized at lifting-time and are unusually soft, or become so after a short time in store, the presence of bulb scale mite may be suspected. A few bulbs should be cut through transversely near the neck, as is done for the preliminary diagnosis of eelworm attack. If scale mites are present there will be small brown patches, usually at angular points in the scales (Plate VI). If the scales are parted, or if the bulb is cut vertically, streaks of yellow-to-brown tissue, running lengthways in the bulb, will be found at these points. Examination under a dissecting microscope will disclose the mites, eggs and cast skins congregated on or near the discoloured areas. These areas normally become calloused and it is unusual to find decay of the bulb scales unless some other pathogen is present, for example, smoulder disease (*Botrytis narcissicola*). Bulb scale mite on its own does not rapidly kill a bulb but constantly saps its vitality.

IN THE FORCED CROP

Before bulbs are boxed for forcing, the grower should make sure that bulb scale mite is not present in the stock; if infested bulbs are subjected to the comparatively high temperatures needed for forcing, the mite population increases rapidly. The mites congregate in the bulb neck and are often so numerous that the basal region of the leaves appears to be covered with a greyish dust. The leaves appear first abnormally bright green, becoming distorted, streaked and flecked with yellow as the mites continue to feed (Plate VII). Sometimes, this damage may be confused with the 'leaf-stripe' symptoms of virus infection.

While the effect of attack upon the foliage may be serious, it may be disastrous upon the flowers. The congregation of mites at the neck of the bulb coincides with the time that the flower bud is being protruded and in extreme cases flower bud and stem are both killed. More commonly the bud is killed but the stem continues to lengthen, bearing a characteristic 'saw-edge' and carrying a dead flower bud at its tip. Sometimes this condition is attributed to faulty management when, in fact, the mite is responsible.

IN THE FIELD CROP

In outdoor bulb crops a prolonged infestation of bulb scale mite has a cumulative effect. The symptoms are rarely more pronounced than a general lack of vigour, the production of inferior blooms and premature death of foliage, so the pest is often difficult to diagnose in the field. Serious injury resembling that described in forced bulbs only rarely occurs outdoors but there is one noteworthy difference between the two kinds of damage. Plant growth is slower outdoors and the mites concentrate upon the young leaves before the flower bud has made appreciable growth. In extreme instances leaf growth may be almost completely inhibited, yet the flower stem manages to emerge intact and to produce a bloom, always small, usually imperfect and without any accompanying foliage. This effect has been observed in several localities, always in exceptionally dry and warm springs. Bulbs so affected are unable to replenish their food supply during the growing season and rapidly degenerate.

Control Measures

Immersion of infested bulbs in a hot-water bath at 110°F (43·3°C) for an hour will kill most of the active stages and eggs of bulb scale mite but complete eradication cannot be expected unless the bulbs are so treated for four hours at 110°F or for three hours at 112°F (44·4°C). For forcing during the season immediately following treatment, a good crop of flowers may be taken after treatment for one hour at 110°F with least risk of loss of bloom due to the hot-water treatment (see pp. 32–34 for advice about the timing of treatment), or failure due to bulb scale mite. However, if a stock is intended for growing-on outdoors it is necessary to increase the time or raise the temperature of hot-water treatment. A treatment should be given every two years to ensure complete success. Recently it has been shown that a cool dip at 65°F (18·3°C) of 0·2 per cent thionazin with 0·1 per cent of a non-ionic type wetter gave a similar degree of control to hot-water treatment at 111°F (43·9°C) for three hours.

A serious infestation may be overlooked until it is too late for hot-water treatment to be practicable, or it may not be detected until the bulbs are brought indoors for forcing. If the infestation is discovered soon after the bulbs are housed, drenching sprays of 0·1 per cent endrin or endosulfan will save a good proportion of the blooms. Both chemicals are scheduled poisonous substances (see 'Precautions', p. 40). Drenching should be done as soon as possible, but frozen boxes should be allowed to thaw out before treatment. The spray should be liberally applied and carefully directed into the centres of the plants using a watering can with a fine rose or a knapsack sprayer working at low pressure. Even the most efficiently applied chemical treatment gives only a partial kill, allowing only a temporary respite for the plants, because a great number of mites remain safely inside the bulbs where the chemical does not penetrate. However, if bulbs are heavily infested, such treatment checks the mites sufficiently to allow the flowers to develop normally and for much of the foliage to be comparatively free from severe blemishes. If the bulbs are to be reclaimed after forcing, they must be hot-water treated before replanting.

Bulb scale mites soon die in the absence of the host plant, so that when heavily infested bulbs are lifted, provided all groundkeepers are removed, reinfestation of a clean stock from the soil is most improbable.

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BULB MITES

P. Aitkenhead

Mites of the genus *Rhizoglyphus* have been associated with damage to various plants, especially the popular bulb flowers, hence the name bulb mites. Their frequent occurrence in stocks of bulbs shows that these pests are well established in the bulb-growing areas of Britain and Western Europe. Whether *Rhizoglyphus* mites are native to Europe is doubtful, and it appears more likely that they were introduced from warmer areas.

IDENTIFICATION

The mites (Plate VIII) are plump, glistening, whitish creatures, and are large compared with the bulb scale mite, and more ponderous in their movements. The adult females are up to $\frac{1}{25}$ in. (0·9 mm) long, the males being a little smaller. Both sexes have four pairs of stoutish legs (cf. bulb scale mite). The young stages except one, resemble the adults, but have only three pairs of legs. The exception is the hypopus, a specialized immature stage that develops in adverse conditions. The hypopi resemble minute shiny brown tortoises; they are abnormally resistant to starvation and are adapted for attaching themselves to larger creatures as a means of dispersal. The eggs of bulb mites are pearly-white and up to $\frac{1}{120}$ in. (0·2 mm) long.

LIFE HISTORY

Bulb mites will continue to develop and breed as long as conditions are suitable. Mated females deposit their eggs singly on the surface of areas where they are feeding. Eggs are laid over a period of several days (or longer) and one female may lay up to 100 or more eggs. The newly-hatched mites resemble the adults in appearance; they feed amongst the moist and decaying tissues, moulting three times during their development into adults. The total time taken for development varies greatly between individuals in the same culture, temperature clearly exerting a powerful influence. For example, at 70°F (21°C) the life cycle may be completed in about 27 days, whereas temperatures below 53°F (12°C) and above 95°F (35°C) seem to inactivate the mites.

Damage to Bulbs

Small colonies of bulb mites are likely to develop on any parts of the bulb that are in a suitable state of decay. These may be naturally senescing scales or leaves and areas mechanically damaged or affected by other diseases or pests. The infested areas turn brown and become dry and mealy, with bulb mites scattered throughout. There is some evidence that bulb mites can aggravate the effects of progressive troubles, for example stem eelworm, but although it has been suggested that the mites spread infections from bulb to bulb, there is little evidence to support this.

If bulbs are in poor condition, e.g., due to stem eelworm attack or to long periods in transit, high populations may develop and perhaps cause direct damage or aid the spread of infectious bulb diseases.

Control of Bulb mites

Any of the treatments used to control or eradicate stem eelworm or bulb scale mite in the lifted bulbs will be effective against bulb mites. Stocks substantially damaged by eelworm are probably very susceptible to attack by bulb mites. To prevent reinfestation after hot-water or thionazin treatment such stocks should be carefully dried and given cool, airy storage conditions well isolated from untreated stocks. Bulbs for sale should be despatched before there is any chance of their starting into growth and they should be packed in a way that gives protection and allows aeration.

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Hot-Water Treatment of Narcissus Bulbs

A. L. WINFIELD

THE first experiments in England on the hot-water treatment of narcissus bulbs in the early part of this century were made by J. W. Barr and J. K. Ramsbottom. Since then certain refinements and modifications of their process have been introduced and hot-water treatment continues to be the most effective method for controlling stem eelworm. It also controls large and small narcissus flies, bulb scale mite and bulb mites (see pages 6, 8, 24 and 27, respectively).

Hot-water treatment involves placing bulbs in a bath of water held at a constant temperature for a certain period of time. There is only a small margin between killing the pests and damaging the bulbs, and hot-water treatment must be very carefully carried out and correctly timed. Inefficient makeshift equipment, good equipment inefficiently used, or incorrect timing of treatment, can result in poor control of the pests, especially of stem eelworm, or serious damage to the bulbs.

EQUIPMENT AND ITS OPERATION

Efficient equipment is available nowadays that is easy to operate and that can deal successfully with up to half a ton of bulbs at a time; at the time of writing even larger baths are coming into use. The important features of a good commercial installation for hot-water treatment are:

the shed is separate from that used as bulb store and is so constructed that there are 'dirty' and 'clean' sides, with a permanent wall or partition between them; the shed is free from draughts, otherwise eelworm-infested or diseased bulb debris can be blown into the area where treated bulbs are standing, and air currents can reduce the efficiency of the installation by causing uneven cooling of the hot-water tank;

the hot-water tank is sited between the 'clean' and 'dirty' sides, preferably in a separate compartment;

the dividing wall has no doors, so that operators and vehicles cannot move directly from 'dirty' to 'clean' sides;

the apertures in the dividing wall are large enough to allow only bulb-containers to pass through and such apertures are kept closed when not in use. All doors are closed whilst bulbs are being put into, or taken out of, the tank.

If the hot-water treatment shed is properly designed, bulbs will pass smoothly through the process in one direction only, from their reception at the 'dirty' side, into the hot-water tank and through to the 'clean' side of the shed. As an additional precaution against recontamination of treated bulbs, some modern installations have a shallow sump, built into the floor, across the doorway of the 'clean' side. When bulbs are being treated the sump is filled with a strong disinfectant solution (e.g., solubilized cresylic acid), through which all operators and wheeled equipment must pass before entering or leaving the shed. All boxes or other containers used for storing bulbs should be dipped in cresylic acid or formaldehyde solution before they are used for storing bulbs which have been hot-water treated. The shed itself must be easy to keep clean; exposed rafters and ledges that can accumulate dust and debris should be avoided.

When the installation of new equipment is being considered, it is advisable to plan well ahead so that the tanks and their ancillary equipment are large enough to cope with future demands. It is better to have a surplus operating capacity for a few seasons than to have to re-equip or re-design buildings later on.

The shape of the hot-water tank is not the most important consideration, but usually a rectangular tank is cheaper than a cylindrical one. It is more difficult to obtain good circulation of water in a rectangular tank than in a cylindrical one, but all installations must include an efficient circulating pump. Many cylindrical tanks that have been designed for convection circulation can be adapted to modern forced circulation. The pump should be capable of circulating at least four times the volume of water in the tank each hour. Inlet pipes from the pump are arranged so that the water spreads out evenly over the bottom of the tank, through a series of perforated holes pointing sideways or downwards. The suction pipes at the top of the tank should draw water from as large an area as possible. This suction can be through a series of horizontal holes, or from several points, e.g., the corners of the tank. Whichever arrangement is used filters must be incorporated in the suction pipe to protect the pump against debris and other solids suspended in the water. It is important to keep the water level well above the tops of the inlet pipes. This prevents the suction of air into the system and reduces frothing if a wetter is used.

There are three main methods of heating the water in the tank: steam, electricity, or a combination of both. Direct heating by gas or oil is extremely difficult to control and should be installed only in exceptional circumstances. Electric heating is easily controlled by a temperature controller (thermostat) and, if the tank is well lagged, consumption of electricity is not excessive, even when powerful immersion heaters are installed. The thermostat should have a short temperature range, say 80–140°F (26–60°C), to ensure maximum sensitivity. However, even the best control unit may suffer from small but important scale errors and must always be checked against an accurate thermometer (see p. 31). Heating by steam is the quickest method, but while bulbs are being treated the pressure of steam supplied to the heating coil (calorifier) in the tank should not exceed 5 lb per sq in. An ideal method is to heat initially with direct high pressure steam, changing over to electric, thermostatically controlled heating as soon as the bulbs are put into the tank. Steam can be used again for raising the temperature of the tank between loads. Direct heating by steam injection must not be used when bulbs are in the tank; during this time steam must only be used at low pressure through the calorifier. A 'topping-up' tank, heated electrically or by steam, controlled by a separate thermostat and maintained at about 140°F (60°C), is a useful extra piece of equipment for speeding up the throughput of the installation.

The tank should be efficiently lagged to prevent heat loss. It is pointless to use extra fuel or power simply to heat the surrounding air, and lack of insulation will also lead to temperature fluctuations at various places in the tank. A close-fitting lid will eliminate much of the heat loss at the water-to-air interface at the top of the tank.

All installations should have easily operated and adequate lifting devices for loading and unloading. The boxes, crates or wire-baskets are loaded with bulbs, and are then stacked on to a wooden or tubular metal pallet. When the pallet is loaded with bulbs, the whole consignment can be lifted into the tank. After treatment the pallet is raised above the tank and the bulbs are allowed to drain for a few minutes before the containers are unloaded and dispatched to the 'clean' side.

The bulbs should be treated in rigid wire-mesh or wooden containers designed to fit the tank. Some shapes pack very badly into the tank so that much of its capacity is wasted. If rigid containers cannot be obtained, nets may be used, provided that they are open mesh (at least $\frac{1}{4}$ in (6 mm)), filled about three-quarters full and tied at the top. If nets are used it must be realized that the treatment may be less efficient than with rigid containers, and a good control of stem eelworm will be harder to obtain. Never use sacks. Always allow ample room in containers for the bulbs to swell during treatment. Stack the containers in well separated layers so that water can circulate freely between them, and do not overload the tank; there should never be more than one part by weight of bulbs to three parts by volume of water, e.g., $\frac{1}{2}$ ton of bulbs to 350 gal water.

The working temperature of the tank should not be set by the thermostat scale alone. This is because, as mentioned on p. 30, there may be scale errors, and the sensitive element of the thermostat is usually fixed in a permanent position in the apparatus and may therefore record a temperature slightly different from that of the main bulk of water. After setting the thermostat to the working temperature, use a mercury-in-glass thermometer to check the actual water temperature at various places in the tank. Thermometers enclosed in brass or other protective cases are useless. The thermometer must be accurate, and should be compared regularly with one that has been checked by the National Physical Laboratory. Calibrations should read from 100–130°F (37·8–54·4°C) and the body of the thermometer should be about 18 inches (45 cm) long so that quarter degrees can be clearly read. If the water temperature, as read by the mercury thermometer, differs from the correct working temperature, the thermostat setting should be readjusted. When the temperature remains constant at the required temperature for about ten minutes, the thermostat is correctly set, and will maintain the water at the correct temperature thereafter.

When a load of bulbs is put into the tank the temperature drops. Therefore, the time that treatment starts is not when the bulbs are first immersed, but when the water has regained the correct temperature. The speed with which the working temperature can be regained depends mainly on the heating system that is used; it is reached quicker with steam-heated installations than with electric immersion heaters, although a 'topping-up' tank held at a higher temperature (as mentioned above) can considerably speed up the operation.

Between each load of bulbs it is advisable to clean off the scum and debris from the top of the water, and the water should be changed as soon as it becomes obviously dirty. The continued use of very dirty water increases the risk of contamination. The frequency of water changes will depend on whether or not the bulbs are soiled and on the health of stocks being treated. Many growers prefer to treat their healthiest stocks first and those suspected of being least healthy last of all.

SEQUENCE OF OPERATIONS

Pre-treatment of Bulbs

The conditions under which bulbs are stored immediately after lifting affect their ability to withstand hot-water treatment. Some varieties are inherently more susceptible to hot-water damage than others, and recently it has been found that cool storage temperatures, e.g., 50°F (10°C) immediately before treatment result in more pronounced hot-water damage than warmer storage temperatures, e.g., 65°F (18·3°C) or higher. Warm storage for one week at 86°F (30°C) or four days at 93°F (33·9°C) immediately before hot-water treatment can reduce damage to the flowers the following season, or even eliminate it, even with some of the more sensitive varieties. However, recent experiments with eelworm-infested bulbs in Britain and in the Netherlands have shown that warm-storage results in a poorer control of stem eelworm. If stocks are known to be more than very lightly infested with eelworm, they should not be warm-stored.

Recent experiments have shown that pre-soaking in cold water with added wetter for three hours, before hot-water treatment, improves the control of stem eelworm, but in some instances bulbs have been damaged by this treatment if they were not previously given a period of warm storage (7 days at 86°F (30°C) or 4 days at 93°F (33·9°C). The purpose of pre-soaking is to eliminate air pockets within the dry outer scales and the necks of the bulbs, inside which eelworms may survive hot-water treatment.

It is well established that eelworm 'wool', which consists of desiccated eelworms, is difficult to kill by hot-water treatment. In order to reduce the risk of 'wool' formation, some advisers recommend that the relative humidity be kept high during storage, particularly warm storage, before hot-water treatment. The humidity in the store between lifting and planting should certainly not be allowed to fall too low, but storing bulbs in almost saturated air has its dangers. It may encourage fungal and bacterial attack and, although 86°F (30°C) is well above the optimum temperature for development of basal rot (*Fusarium oxysporum* f. *narcissi*), prolonged storage of infected bulbs in moist air may cause spread of this disease. Moist, warm conditions also encourage root growth and may render the roots susceptible to damage by hot water and subsequent insecticidal dips. Bulbs are usually quite moist when lifted and, if they are not over-dried, this moisture should be enough to prevent desiccation of the eelworms.

Timing of Hot-Water Treatment

Narcissus bulbs should be lifted when the new flower buds inside have reached about stage P_1 or P_2 (see p. 33), usually when the foliage is dying down. Earlier lifting is often permissible but late lifting will cause re-rooting to occur which must be avoided. It must be realized that bulbs cannot be hot-water treated without risk of damage, but the risks can be minimized by timing the treatment carefully in relation to the developing flower buds and root systems. In the eastern counties growers have to treat their stocks over a period of six to eight weeks during July and August. In the south-west treatment begins earlier than in the east, and reclaimed stocks from the forcing programme are usually treated first of all, beginning in late May or

June. Depending both on variety and season, there is an optimum 'safe' period during the summer when hot-water treatment is least likely to cause damage. Generally, the later flowering varieties develop their new buds more quickly than earlier flowering kinds. Contrary to widely held belief, therefore, *poeticus* types should be treated first, followed by cup, and lastly by trumpet varieties. Treatment earlier than this safe period, before all the flower parts are formed in the new buds, can cause extensive flower damage, but this will affect the crop in the following season only. Treatment after the safe period may also cause bud and foliage damage, but more seriously, it may also damage the new root initials. The later the treatment the more serious are the long-term effects; from root damage the bulbs may not recover for several years.

The flower bud for the following season develops inside the bulb during the spring and early summer. Nine distinct stages in its development can be recognized, each corresponding to the appearance of a major flower-part in the bud. From the formation of the leaf primordium (I) and the flower bud initial (II) in early spring, the bud develops as follows: firstly the flower spathe or sheath (sp. stage) is formed around the embryo-bud. Within this the new sepals and petals (perianth) grow in two groups, or rings, each of three segments (P_1 and P_2 stages); then the male stamens (androecium), again in two groups of three, A_1 and A_2. Next, the female carpels (gynoecium (G)), comprising a three-lobed ovary and stigmas, develop in the centre. Lastly comes the Pc stage (paracorolla (cup, trumpet or corona)) within the ring of the perianth.

Plates IX and X show photographs of the various stages of development of a bud of the variety King Alfred; although the timing of these stages will vary with variety, season, location and cultivation, the illustrations are a useful guide for those who wish to do their own bud dissections. The technique is not difficult, but some practice in recognizing the various stages is required; a good quality 10 x magnifying glass, a small sharp knife and two mounted dissecting needles are the only instruments needed.

DISSECTION TO SHOW BUD STAGES

Trim off the old roots and baseplate level with the bases of the outer scales.

Cut off and discard the upper half of the bulb and break off the outer scales of the bottom half, starting with two vertical cuts to make two straight sides.

Break the remaining scales outwards and cut them off, thus leaving only the baseplate, with the main flower bud in the centre enclosed in its sheath.

Carefully slit and cut off the sheath with the point of a mounted needle.

Later in the season or when the sepals and petals have developed inside the sheath, they can be removed with the point of a mounted needle in order to show how far the inner parts of the bud have developed.

The inside of the bud can then be inspected with a hand lens under a good light.

The best time for hot-water treatment is when the bulbs have just reached stage Pc. Treatment before the new buds have reached Pc may cause damage to all the flower parts that are incomplete, resulting in distortion or loss of flowers in the following season. However, soon after the new flower bud has developed, the next year's root initials begin to grow within the baseplate; very serious long-term damage can be caused by hot-water treating bulbs when the roots are emerging from the baseplate. It is better to treat too early and lose a proportion of blooms the following year, than to treat too late and risk reducing the vigour of the stock and causing permanent damage. Early treatment has no effect beyond the following season, but many cases of stock degeneration can be traced to repeated hot-water treatment too late in the season, sometimes several years before the trouble became evident.

The safe period for hot-water treatment of narcissus, therefore, is normally in July and August. The precise timing can be narrowed down still further by examining the flower buds and new root systems, as described on p. 33, and by keeping carefully records of the individual stocks, so that previous experience is accurately recorded. It is most important to make careful notes on each year's results, particularly with new varieties, and to use these notes as a guide to future treatment.

Recent Dutch work has supported observations and experience in this country that hot-water treatment as soon as possible after lifting gives the best control of stem eelworm. Later treatment is always less satisfactory. A relatively small infestation of eelworms can build up in stored bulbs to a very serious level; bulbs apparently sound but lightly infested in July can become rotten by late September. Populations of eelworms in such bulbs will increase enormously during this time. Therefore, besides avoiding the possible ill effects of late treatment on the bulbs themselves, early treatment is better because there are then fewer eelworms to kill, fewer desiccated eelworms on the outer dry scales and less decomposed tissue inside infested bulbs, to hinder the penetration of heat into the bulbs and so to reduce the effectiveness of the whole process.

Additives to the Hot-Water Tank

It is advisable always to use a wetter or spreader in the water. Most of the kinds sold specially for horticultural purposes are satisfactory, but care should be taken to follow the maker's recommendations for their use. A wetter increases the penetration of damaged bulbs by water and reduces the amount of insulating air bubbles in the bulb neck and scales.

Fungicides may also be added to the water. Suitable materials are commercial formalin, which is a 40 per cent solution of formaldehyde, or one of the organomercury compounds sold specifically for the purpose (but see 'Precautions', p. 40). Use formalin at a rate of one gallon to 200 gallons of water and the mercury compounds, only where basal rot is a problem, at manufacturers' recommended rates. Formaldehyde is toxic to eelworms contaminating the outsides of bulbs, which, being desiccated, are usually the ones most difficult to kill; it has also been shown to have a beneficial effect on the bulbs themselves. Formalin is usually a safe material, but damage by too-late treatment may be increased if it is used. In spite of its pungent smell when the tank is open, formaldehyde is lost from a hot-water tank very slowly. The tank is topped-up with formalin or other additives whenever fresh water is added, the proportions of additives to water being kept the same as in the initial mixture.

Duration and Temperature of Treatment

The traditional hot-water treatment in Britain was 110°F (43·3°C) for three hours but this has proved inadequate to give the high standard of control demanded by growers. Recently it has been shown that as much as four hours treatment may be needed to kill eelworms suspended in water at 110°F, although they are killed more quickly in bulb tissue than in water. Since about an hour is needed for heat to penetrate to the centre of a medium-sized bulb, this suggests that a minimum time of five hours at 110°F would be needed for complete eelworm control. For larger bulbs, or if the eelworms have become more resistant as a result of desiccation, an even longer treatment time would be necessary.

These results are borne out by experience in the Netherlands, which showed that treatment for four hours at 110·5°F (43·5°C) could not be relied upon to eliminate stem eelworm. An improvement in control methods was therefore needed by increasing either the time or temperature of treatment. Increasing the time to five or six hours would mean that only one load could be treated in a working day and would be impracticable because few growers could then treat all their bulbs during the safe period. Under ideal conditions bulbs can survive prolonged treatment at temperatures up to 115°F (46°C) without apparent reduction in growth or vigour. In practice, however, some damage is likely if the water temperature exceeds 113°F (45°C), especially if the bulbs have not had a period of warm storage before treatment. The present recommendation is, therefore, to hot-water treat *for three hours at a temperature of* 111–112°F (43·9–44·4°C).

This treatment should give satisfactory control of stem eelworm without damage to the bulbs. It will also control large and small narcissus flies, bulb scale mite and bulb mites but it cannot be relied upon to kill the 'wool' stage of the eelworm. Work in this country and in the Netherlands has shown that even five hours' treatment at 113°F (45°C) will not give satisfactory control of eelworm if the bulbs have been allowed to become too dry, for example, by warm storage at too low humidity.

After-Treatment of Bulbs

After removal from the hot-water tank the bulbs are allowed to drain and are moved without delay into the clean storage shed to avoid reinfestation by pests and diseases. The bulbs are then cooled gradually to a normal temperature; this is easily done by spreading them out in trays or shallow boxes. Sudden cooling can result in serious damage to some varieties, and bulbs should never be plunged into cold water to cool them. Crates, boxes or net-bags should be stacked so that air can circulate freely and assist cooling. It is best to plant bulbs as soon as they have cooled, and they may be planted before they are fully dried. When the bulbs are not to be planted immediately after treatment they must be thoroughly dried before further storage or despatch. If they are left in the containers in which they were treated, cooling may be too slow which, in effect, prolongs the hot-water treatment for a further, unknown, period of time; this will damage the bulbs. If stored wet for prolonged periods bulbs will root prematurely.

SYMPTOMS OF INJURY CAUSED BY HOT-WATER TREATMENT

Treatments carried out too early and too late cause different types of damage and it is important to differentiate between these, but some symptoms may be produced by excessive treatment at any time. The symptoms are described below; they may be more or less pronounced, depending on the variety and on duration, temperature and timing of treatment.

DAMAGE TO FLOWERS

In the most extreme forms of injury the flower buds are killed within the bulb and fail to appear, or the flower stem may emerge normally and elongate bearing a dead flower bud; some buds may be so weakened that they cannot open the spathe. The latter injury can result from very late treatment, or possibly in some varieties, e.g., Double White, from drought during the growing season. Where the flower does appear it may show every gradation of injury; dwarfing is common especially in the variety Carlton, and, if treatment was very early, may be accompanied by severe laceration of the petals and cup. Sometimes only the rim of the cup is more or less frilled or notched (split flowers) (Plate XI). Flower injury does not persist into the second season after treatment and is almost invariably due to premature treatment.

DAMAGE TO FOLIAGE

One of the commonest symptoms of hot-water injury is a pale-green yellowish or greyish mottling near the tip of the leaf. There may be all gradations from a faint speckling to large mottled areas that feel distinctly rough. The degree of leaf injury depends on the variety and the date of hot-water treatment; within limits the later the treatment the more severe is the mottling. In many trumpet varieties treatment given more than six weeks after lifting nearly always causes a rough mottle to appear on the leaves the following season, but in several other varieties discoloured-leaf symptoms may not show, although the leaves may be smaller or have slight distortions that may go unnoticed. On some of the trumpet varieties the outer leaf may become curled and lie flat on the soil.

Hot-water effects on leaves are similar to some symptoms of leaf stripe virus disease. Virus stripes are sometimes roughened and nearly always turn yellow or lighter green in colour, but these effects are usually most marked some distance from the leaf-tip, whereas the more rounded marks of hot-water injury are concentrated near the tip. However, leaf markings caused by hot-water can become elongated as the leaf grows (Plate XI), and sometimes the symptoms caused by virus and by hot-water injury are inextricably mixed on the same plant.

DAMAGE TO BULBS

In narcissus bulbs, hot-water injury, often following too lengthy or too hot treatment, usually shows as irregular greyish areas within the bulb. External bruising also causes the fleshy scales to turn grey near the point of impact, but hot-water injury is usually seen deeper in the bulb, often spreading up and around the scales from the baseplate. Simple bruising is usually worst in outer fleshy scales.

GENERAL REMARKS

Although mild foliage injury is of little economic importance, it is a useful warning that the previous season's hot-water treatment was done either too late, or perhaps at too high a temperature. Serious decreases in bulb yields can occasionally follow hot-water treatment, and the foliage symptoms may indicate the cause. If treatment is given very late, or at too high a temperature, particularly after the roots have begun to form, the resulting root injury may prevent the plant from making good growth in the following season; sometimes foliage may not appear above the ground and the bulbs are considerably weakened. Repeated mismanagement of hot-water treatment will eventually so weaken a stock of bulbs that it becomes almost worthless.

Damaged scales (brown rings) caused by eelworm attack will persist for one or two years after hot-water treatment although the eelworms in them are dead. In the laboratory this kind of brown ring is relatively simple to distinguish from those in which live eelworms are feeding and breeding. It is very important to detect stem eelworm in a stock before the pest becomes too well established for hot-water treatment to be effective; it is worth repeating that to treat decomposing bulbs is useless. Hot-water treatment cannot restore the tissue already destroyed. Extensive decayed areas inside the bulbs will make them more susceptible to injury from other pests and fungus diseases during their first year after replanting. The treatment will accelerate decay, which may then spread to other newly-treated bulbs. Furthermore, decayed bulb tissue may hinder the penetration of heat into the bulb and some eelworms may survive the hot-water treatment. There is much more likelihood of eelworm 'wool' forming in heavily infested bulbs.

Field roguing every spring and careful examination of all stocks at lifting time will ensure early diagnosis of stem eelworm. Rotten and decayed bulbs should be sorted out and destroyed before hot-water treatment.

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Other Pests attacking Narcissus

A. L. WINFIELD

SLUGS*

SLUGS can cause considerable losses to the narcissus crop. There are two species mainly involved, the garden slug (*Arion hortensis* Fér.) and the field slug (*Agriolimax reticulatus* (Müll.)). Damage may be worse during a long spell of unduly wet weather and in situations that remain damp.

In the field, damage occurs below ground, especially during December and January when the slugs attack the base of the bulb, allowing rotting organisms to enter; the roots are also attacked by slugs. If the damage is severe the whole bulb may be killed, and if numbers of bulbs are lost the crop of both flowers and bulbs can be seriously reduced. The damage to the baseplate is superficially like that caused by large narcissus fly larvae (see page 7), and both pests cause the subsequent growth of weak, yellowed foliage. Some damage may occur later in the year, when the foliage is attacked.

Bulbs in forcing houses can also be attacked, but this is usually due to the boxes having slugs in them when they are taken in. The temperature and humidity of the forcing house encourage the slugs to wander freely over the crop, and damage can be extensive and serious. They also damage the buds and the flowers, a form of injury that is rarely seen in the field (see Plate XII). It has been noticed that the coloured rim of the cup in *poeticus* varieties seems particularly attractive to slugs, and this damage can render a flower quite unsaleable.

CONTROL

Subterranean attacks by slugs in winter are very difficult to stop, using baits, compared with attacks about or above ground level. Relatively few of the subterranean-feeding slugs find any of the poison bait, and in any case slugs may be more attracted to the plants than to the bait.

At present there are two effective chemicals for the control of slugs, methiocarb and metaldehyde, both formulated as bran pellets. The conventional metaldehyde pellets are fairly large, and are used at 28 lb per acre, and the smaller methiocarb pellets at 5 lb per acre. There is now a smaller pellet available, containing six per cent metaldehyde, which is used at 14 lb per acre. Generally speaking, the smaller pellets provide more killing-points per unit area, and are more effective than the larger pellets.

As treatment of the growing crop against subterranean attack is of little value, only a pre-planting treatment is feasible. Pellets should be applied to weed-free soil, which has been lightly broken-up, and when the weather is mild and moist, because slugs are active under these conditions. It is useless to apply pellets during cold, dry weather, or when the soil surface is very dry, very cloddy, or capped.

*See also Advisory Leaflet 115, available from the Ministry (p. 40).

Control under glass is also difficult because the moist condition of the soil in the boxes causes the pellets to swell and lose their activity more quickly than outdoors. It may be necessary to give two or more applications of methiocarb or metaldehyde pellets, but much depends upon the conditions in the glasshouse.

SWIFT MOTH*

Caterpillars of the garden swift moth, (*Hepialus lupulina* (L.)), can attack bulbs. Attacks have been noted on narcissus each year in certain parishes of south-east Lincolnshire. The first sign of an attack is irregular growth in the spring. Later on gaps can be seen where plants have not emerged. Rarely, the whole field may be affected, with only a few plants growing normally.

The adult moths emerge in mid-May and June and lay their eggs (between 50 and 200) whilst in flight, choosing land with some cover on it, such as grass or weedy narcissus crops. The eggs hatch after 10 to 14 days, and the young caterpillars burrow into the soil and attack the bulbs (Plate XII). When there is a good food supply the larvae complete their development in one year. Feeding continues throughout the winter, with a peak in February and March. The chrysalis is formed in a silk lined tunnel in the soil, close to the bulbs, during April, and the adults emerge about a month later.

The damage may be confused with that caused by the large narcissus fly, the chief difference being that the swift moth caterpillars make large round holes in the sides of the bulbs while the fly larva makes a hole only in the baseplate. In the spring, tunnels made by the caterpillars may often be found in the soil. The tunnels are near the rows of plants and resemble those made by earthworms, but differ in that there is no cast. With care it is possible to dig away the soil, and by following the tunnel, to find the caterpillar or chrysalis. These can be about 12 to 18 in. (30 to 45 cm) deep.

CONTROL

At present there is no control method that is effective. The absence of weeds in a crop of narcissus will render the site unattractive to the moths, which suggests that weeds should be well controlled from mid-May onwards, when egg laying starts. As some moths are on the wing in August and September weed control should continue at least until this time.

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*See also Advisory Leaflet 160, available from the Ministry (p. 40).

Precautions

WHENEVER pesticides are used, read and follow carefully the instructions on the label. Users should also consult the 'Recommendations for Safe Use of Chemical Compounds Used in Agriculture and Food Storage' published by and obtainable free from the Ministry of Agriculture, Fisheries and Food, Safety, Pesticides and Infestation Control Division, Great Westminster House, Horseferry Road, London, S.W.1. Use the pesticides mentioned in this Bulletin with care, particularly:

- aldrin
- gamma-BHC
- dichloropropane-dichloropropene mixture (D-D)
- dichloropropene
- endosulfan*
- endrin*
- formaldehyde
- organomercury compounds**
- thionazin*

and wash off any concentrate that falls on the skin. 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, waterways or ditches with concentrate, spray or washings.

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*There are statutory obligations affecting employers and workers who use certain pesticides, including endosulfan, endrin and thionazin. Users of these chemicals are strongly advised to read the Ministry's Leaflet APS/1, 'The Safe Use of Poisonous Chemicals on the Farm', obtainable free from the Ministry at the address below.

**Bulb dips (Steeps) containing organomercury compounds should be used *only* in premises registered under the Factories Act, where regular expert inspection can ensure the safety of the treatment process.

AGRICULTURAL CHEMICALS APPROVAL SCHEME

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 of charge on application to the Ministry of Agriculture, Fisheries and Food (Publications), Government Buildings, Block C, Tolcarne Drive, Pinner, Middlesex HA 5 2 DT, or any Regional or Divisional Office.

AGRICULTURAL CHEMICALS APPROVAL SCHEME

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