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## Research Report

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The bulb scale mite.

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# LITERATURE REVIEW FOR CSL CONTRACT No. CC06077

# The bulb scale mite, *Steneotarsonemus laticeps* (Halbert) - a review

by

SOPHIE M LYNCH

# *STENEOTARSONEMUS LATICEPS* (HALBERT 1923) (THE BULB SCALE MITE) - A REVIEW

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# PART 1 - BIOLOGY

## Nomenclature and Taxonomic History

Synonyms

*Tarsonemus laticeps* Halbert 1923
*Tarsonemus approximatus* Banks var. *narcissi* Ewing 1929
*Tarsonemus hydocephalus* Vitzthum 1929

*Steneotarsonemus laticeps* (Halbert 1923) was first described by Halbert in 1923, as *Tarsonemus laticeps*, from partly decayed *Narcissus* (Amaryllidaceae) bulbs in County Dublin, Ireland (see Fig. 1 a, b). The origin of the bulbs was uncertain. The type specimens are in the Irish National Museum, Dublin.

It was subsequently described by Ewing (1929) as *Tarsonemus approximatus* Banks var. *narcissi* (see Figs 2 & 3), a new variety taken by C F Doucette in 1926, from stems, leaves and flower buds of *Narcissus*, from San Leandro, California, USA, and by D Griffiths in 1928 from *Narcissus* bulbs from Bellingham, Washington, USA. The type specimens of *T. approximatus* var. *narcissi* Ewing are in the U.S.N.M.. In the same year, 1929, it was also described as *Tarsonemus hydrocephalus* by Vitzthum (1929) (see Fig. 4), from specimens taken by Tullgren from *Pancratium* sp. (Amaryllidaceae) from Stockholm, Sweden.

In his review of the Tarsoneminae of North America, Ewing (1939) synonomised *Tarsonemus approximatus* Banks var. *narcissi* Ewing and *Tarsonemus hydrocephalus* Vitzthum with *Tarsonemus laticeps* Halbert, and redescribed *T. laticeps* in greater detail. For this description he examined Halbert's original material of *T. laticeps* together with additional specimens of *T approximatus* from North America off *Narcissus* and *Hippeastrum*. In addition he also studied English material taken from *Narcissus* by W E Hodson in 1932, and concluded that there were no differences between the English and North American specimens and that *T. laticeps* Halbert 1923 and *T. approximatus* Banks var. *narcissi* Ewing were one and the same species. He did note and list a number of differences which he observed when comparing the hind leg of *T. approximatus* var. *narcissi* with Vitzthum's figures of the hind leg of *T. hydrocephalus*. There were also other differences, that Ewing observed, between specimens of var. *narcissi* and the Vitzthum drawings, although he does not mention what they were. However, despite this, he decided to synonomise *T. hydrocephalus* with *T. approximatus* var. *narcissi* and *T. laticeps*, based on the agreement of several other characters used to identify the species.

Beer(1954), in his revision of the Tarsonemidae of the Western Hemisphere, erected the new genus *Steneotarsonemus* into which he transferred *Tarsonemus laticeps* (see Fig. 1 c & d) based on a

number of taxonomic characters diagnostic of the genus. Its position in this genus was accepted by Lindquist (1986) in his revision of the World genera of Tarsonemidae.

## Description

*Steneotarsonemus laticeps* (Fig. 5) is a member of the Family Tarsonemidae, a group of mites having a greater diversity of feeding habits than any other Family of the Acari. Many are phytophagous, and the group as a whole contains many species of economic importance [e.g. *Phytonemus pallidus* Banks ( The Strawberry and Cyclamen Mite), *Hemitarsonemus tepidariorum* Warburton ( The Fern Mite) and *Polyphagotarsonemus latus* Banks ( The Broad Mite)].The members of the genus *Steneotarsonemus* are all plant feeders and are restricted to feeding primarily or exclusively on monocotyledonous plants.

Adult *S. laticeps* are extremely small. The adult female is approximately 0.2mm in length. The body is ovoid and elongate in shape, colourless and translucent when young, changing to a pale translucent brown as the mite ages (Plate 9). The males are not only much smaller than the females, but the general body shape is markedly different and widest at its mid-point. There are four pairs of legs, the anterior and posterior pair being widely separated. In both sexes (Plates 1 & 2) the fourth pair of legs is modified. In the females these legs are long and thin, terminating in one very long bristle and one shorter one (Plate 3). In the males these legs are modified into strong, thickened, claw-like claspers (Plate 7). Locomotion by females is accomplished by the use of all four pairs of legs. In male Tarsonemids the fourth pair of legs is rarely used for locomotion, most frequently being carried in a semi-erect position above, and behind, the body. These legs are invariably used by the males in transporting female "pupae" and adult females, both of which are carried on the male's back gripped by these legs and fastened to the male by the genital pappilae.

Both sexes often have a conspicuous white stripe or granular area on the dorsal surface and this is thought to be due to the presence of guanine. In addition both sexes are dorsoventrally depressed, as are many other species of *Steneotarsonemus*. This configuration is an adaption which makes them extremely suitable for their activities in the confined spaces between the sheaths and stems of their grass-like hosts or, in the case of *S. laticeps*, between the narrow spaces of bulb scales.

## Reproduction and Life History

All Tarsonemid mites have four distinct stages in their life history. Eggs are laid singly by the gravid female and are white, ovoid, translucent and large in comparison to the size of the adult. In *S. laticeps* they are slightly more than half the size of the adult female. Eggs hatch into six-legged larvae which, when fully mature, are as large as the adult (Plate 3). Male larvae are smaller in size than female larvae. The larvae are quite active and capable of rapid movement. From the active larval stage the mites enter a quiescent "pupal" stage in which transformation to the adult takes place.

Adult male Tarsonemid mites (Plate 5) generally commence their mating activities by so-called "pre-copulation". The male attaches its genital capsule to the immobile female "pupa", which it carries about gripped between the fourth pair of legs (Plate 6). The male may hold the female in this way for 24 hours until the adult female is ready to emerge. Emergence of the adult females from their larval skins does not normally take place while the females are being borne by the male, but after they have been deposited on leaf surfaces (Lavoipierre, 1940). True copulation generally occurs immediately after the adult female emerges, and before she is ready to feed and disperse. The advantage of pre-copulation is that it affords the male Tarsonemid the opportunity of locating the female while she is still immobile, and therefore maximising the probablity of mating taking place. The observations of Nucifora (1963) and Suski (1972a) indicate that males are remarkably selective in discriminating quiescent individuals of the same species, of the female sex, and which contain fully formed female adults ready to emerge within 24 hours. Occasionally adult females are carried about by adult males in a similar manner to the pupae (Beer, 1954; Schaarschmidt, 1959); presumably such females are newly emerged. These observations apply to Tarsonemids in general, as yet there are no published records of the mating habits of *S. laticeps*.

The life history of *S. laticeps* was studied to some extent by Hodson (1934) under uncontrolled conditions. As he pointed out the concealed nature of the mites' natural habitat made observations under natural conditions impossible. However, despite this, he evolved a method which allowed him to make some useful initial observations. During his first experiments he attempted to rear the mites on portions of bulb scale isolated on damp filter paper in glass cells. Problems with mould growth and the consequent deterioration of the bulb portions made this method impracticable. He also tried using small glass cells, composed of a ring and cover slip, which were applied either to the sides of skinned bulbs or to the foliage. This method was abandoned because of condensation which made observation difficult and which trapped wandering mites.

For his final and more successful observations Hodson raised mites from single adult females which were released onto the surface of individual, very small, dormant bulbs which had had all the outer skins removed. The bulbs were kept individually on dampened filter paper in small solid watchglasses covered by thin sheets of glass and sealed with vaseline. The bulbs were kept in a dark cupboard in a laboratory in which the temperature fluctuated violently and frequently between 40°F and 65°F (4.4°C and 18.3°C). Observations were made from February to April. The original mites were taken from a bulb in February; a time when Hodson states that males are normally scarce and in this particular instance were totally absent. Eight experimental cells were set up and, despite the absence of males, nearly all the females laid eggs which were fertile. Six of the cells were lost at an early stage due to mould growth. However, the remaining two produced strong colonies in which males did not appear until at least the third generation. Hodson suggested that this was evidence for parthenogenesis. Parthenogenesis is indeed common in the Tarsonemidae, but there appears to be a difference of opinion concerning the nature of the progeny produced by this type of reproduction. Garman (1917) found that the progeny resulting from parthenogenetic reproduction in *Phytonemus pallidus* Banks were invariably female, as he reared this species through several generations without the appearance of males. Gadd (1946), however, found that unfertilised eggs of *Polyphagotarsonemus latus* (Banks) produced only males. Beer (1954) also recorded that only males were produced by parthenogenesis when rearing *Tarsonemus setifer* Ewing and *T. randsi* Ewing. According to Lindquist (1986) the complete absence of males is not necessarily indicative of parthenogenesis. Males may be scarce not because of unbalanced sex ratios, but also because they are shorter lived than females. Karl (1965b), White and Sinha (1981) and Flechtmann and Flechtmann (1984) observed that an adult female, which was unfertilised and gave rise to all male progeny, could subsequently mate with one or more of her male offspring and then produce mostly female progeny. This is one of the advantages of adult females living for a considerably longer time than adult males. Lindquist (1986) states that the female:male sex ratio in the progeny of mated females varies considerably within a species, and even more so between species. However, in species of *Steneotarsonemus*, males are, on the whole, said to be relatively common in randomly collected samples.

In his experiments Hodson (1934) found that the number of eggs laid per female ranged from 5 to 28. The individual which laid 28 eggs lived for 30 days after being isolated. She was, however, of unknown age when picked out initially and so she may have been considerably older than 30 days. According to Lindquist (1975) the longevity of adult female Tarsonemids varies greatly according to temperature, season and synchrony with hosts. Generally, in the field, they appear to live for at least two weeks during the rapid turnover of generations in the summer, and probably for at least two months in the winter in warm temperate regions. In regions with harsh winters Tarsonemids overwinter

primarily, if not exclusively, as adult females. This may explain the low numbers or absence of males in the bulbs during the cold months of the year. Adult males are generally relatively short-lived, surviving about one week during the summer. However, Lindquist (1986) states that in some species of *Steneotarsonemus*, such as *S. laticeps*, adult males may be expected to survive for several weeks as the life histories are relatively long, and the number of generations per year few. Although Hodson (1934) suggests that he obtained males in the third generation, he does not give any indication of their longevity.

In Hodson's experiments the eggs were laid singly and the mean duration of the egg stage was found to be 11 days, and varied between 8 and 16 days. The larvae were not reisolated so the exact duration of the larval stage was not established, although the first larva became quiescent 16 days after the first egg hatched, and was followed shortly by others, suggesting an approximate larval period of 15 days. The "pupal" stage was observed to last 3 days in several individuals. Hodson concluded that, under the stated conditions, the life cycle from egg to adult took approximately 7 weeks. However, as he points out, the rapidity with which the mites multiply at higher temperatures (e.g. during the forcing process) indicates that the life cycle could be considerably shortened, possibly to 10 or 12 days. Conversely at low temperatures in winter and early spring it may extend to 3 or more months.

According to Beer (1954) optimum environmental conditions for the various species of Tarsonemidae studied appear to involve a combination of warm temperatures, high humidity and low light intensity. Tarsonemid mites are known to be able to survive in the adult stage through prolonged exposure to freezing temperatures, but seem sensitive to temperatures above 35°C. Garman (1917) reports that a relative humidity of from 80% to 90% is optimum for *S. pallidus*.

In his experiments on *S. laticeps* Blattny (1933) found that the mites were negatively phototropic, were active between 10° C and 20°C and became motionless at 3.5°C, at which temperature no eggs hatched. He found that conditions during the dormant winter stage and the bulb forcing time made a significant difference to the course of an infestation. His experiments were conducted with Amaryllis and he found that light, cold and dry air were unfavourable to to the mites and, consequently, useful in preventing the rapid build-up of problems. In an experiment, bulbs, kept over winter at 8-12°C and 70-95% RH in darkness, showed a 30% infestation rate compared with 10% in bulbs kept similarly at 2-6°C and 40-75% RH in light. Leaving the bulbs out in boxes to be frosted, prior to forcing, has also been found to check infestations (Anon., undated).

Fox-Wilson (1939) states that Mr C Cookson (pers. comm. 6 Feb. 1939) observed that Amaryllis bulbs showing the least signs of

attack were those placed the previous year in a frame in which the temperature rose to 32 - 35°C for short periods. Fox-Wilson goes on to observe that although the thermal death point of the mites varies from 100 - 120°F (37.8 - 48.9°C) it was not known whether the reduction in attack reported by Mr Cookson was due entirely to the high temperatures prevailing in the frame, or to other factors (e.g. The normal decrease in the mite population that occurs during the summer owing to the mites' intolerance of dry conditions. Griffiths (1930) states that *S. laticeps* infestation is much less pronounced in regions having warm summers.

## Records, Distribution and Hosts

The early records by Halbert (1923) from Ireland, Vitzthum (1929) from Sweden and Ewing (1929) from the USA have already been referred to (p.1).

Although not described from America until 1929 (Ewing, 1929), infestations by the mite on *Narcissus* bulbs in the USA had been observed by Doucette (1929) from 1925 onwards. Two heavy infestations of the mite were first observed by him on bulbs imported directly from Holland and which were being forced in greenhouses. One of these was in Philadelphia in the spring of 1925, the other in Oakland, California during the winter of 1925-26. The appearance of the infestations indicated that mites were brought in on shipments from Holland. Over the next three years Doucette observed several widely scattered infestations on *Narcissus* bulbs in the United States and obviously sent the specimens to Ewing who then described the mite. Griffiths (1930) states that although Doucette had found the mite in 1925-26 its importance was not recognised in America until towards the end of some forcing tests in 1927, when it was demonstrated to be injuring stocks.

Massie (1933) recorded *S. laticeps* as *Tarsonemus approximatus* var. *narcissi*, a variety of Tarsonemid new to the British List. The mites were taken from *Narcissus* bulbs grown in Abingdon, Berkshire by W E Hodson, on 25 January 1932. The bulbs had been grown in England for a number of years and in the following months mite-infested bulbs were found in Cornwall, Buckinghamshire and Wiltshire suggesting that the mites' distribution was fairly general. Examples of the English specimens were sent to Dr A C Oudemans in Holland who determined the specimens as *T. approximatus* Banks var. *narcissi* Ewing. Specimens were also sent to Ewing who confirmed the identification and the fact that the English and American specimens were the same species. Staniland and Beaumont (1932) reported that the recently discovered Bulb Scale Mite, *Tarsonemus approximatus* var. *narcissi* had been found at various centres in Devon and Cornwall, both in the open and under glass.

Although these were the first confirmed records of *S. laticeps* in England it is interesting to note that there were possibly two earlier unconfirmed records. According to Moore (1934) specimens of a form of basal rot on Daffodils were exhibited in March 1892 by the Rev. W Wilks at a meeting of the Scientific Committee of the Royal Horticultural Society. These were examined by A D Michael, now considered by many to be the "Father of British Acarology", who reported (Michael, 1892) that two species of mite were present. One was a species of *Rhizoglyphus* and the other, which occurred in great numbers but could not be detected without the aid of a microscope, was identified as a species of *Tarsonemus*, "most like *T. oryzae* Targioni-Tozzetti 1878". Michael (1892) believed this to be the first record of *Tarsonemus* in subterranean structures and considered that it was causing more damage to the bulbs than the *Rhizoglyphus*. Jenkins (1894) revealed that the specimens examined by Michael came from three bulbs (two of *Narcissus obvallaris* Salisb. (The Tenby Daffodil) and one of *Narcissus* x *biflorus*) which had probably been grown in Middlesex. It seems highly likely that the mite concerned was *S. laticeps*, in which case this would have been the earliest record of the Bulb Scale Mite and its association with basal rot disease. An earlier account by Veitch (1890) of the "*Eucharis* mite" on *Hippeastrum* may refer either to *Rhizoglyphus echinopus* (the Bulb Mite) or to *S. laticeps* (the Bulb Scale Mite).

Blattny (1933) first observed the Bulb Scale Mite in 1930 in a greenhouse in Bohemia, and Smith (1934) reported that a mite, known as *T. hydrocephalus*, was discovered to be injurious to Amaryllis in greenhouses in Germany. Hodson (1934) observed that in June 1933 he found the mite to be not uncommon in Germany and that infested stocks had been found on Guernsey, Channel Islands. Labanowski *et al* (1990) recorded the occurrence of *S. laticeps* in Poland for the first time. The mites were found on the leaves and flowers of damaged *Hippeastrum* plants being cultivated in greenhouses in Skierniewice and Waganiec. The mite is thought to have been imported into Poland from Holland in 1981 on *Hippeastrum* bulbs, and is now established and widely distributed throughout Poland.

Jepson and Kiefer (1975) state that *S. laticeps* is found in Ireland, England, Holland, Sweden, and on the west coast of the USA. Alford (1991) gives its distribution as several parts of Europe, England, Ireland, the Netherlands, Sweden and North America.

*S. laticeps* has now been recorded as attacking a large number of the members of the Amaryllidaceae. Although it is considered to be a major pest of *Narcissus*, it is also known to attack *Amaryllis*, *Hippeastrum*, *Pancratium*, *Eucharis*, *Sprekelia* and *Vallota* (Anon., 1984a). Blattny (1933) states that it was possible to breed the mites on a decoction of *Hyacinthus* (Liliaceae) bulbs. This is interesting in view of the fact that although he successfully transferred the mites from *Narcissus*

bulbs to Amaryllis bulbs, attempts to innoculate *Hyacinthus* bulbs proved negative. Gurney (1966) attempted unsuccessfully to infest newly emerging leaves of *Amaryllis*, *Hyacinthus*, *Freesia* (Iridaceae), and *Tulipa* (Liliaceae) with a strain of *S. laticeps* derived from *Narcissus*. A similar comparitive trial made with different cultivars of *Narcissus* was successful, some cultivars exhibiting less serious damage than others.

## Seasonal Biology

The mites live principally between the fleshy scales within the bulb, where they feed mainly on the epidermal surfaces of the scales (Plate 10). The mouthparts, which are contained in the capsular head area, consist of slender, styliform chelicerae which are adapted for piercing (Plate 8).

The bulb scales are leaves, morphologically adapted for food storage purposes. Wherever sufficient space is available between the scales the mites work their way in. In *Narcissus* bulbs such spaces occur because of the tendency of some older scales to form partial folds and convolutions. This is particularly evident around the scale representing the flower stem of the previous year (Doucette, 1936). Spaces also occur due to the removal of stored nutrients during the growing season. Hodson (1934) recorded that when the bulbs are newly lifted towards the end of July, the large majority of mites are congregated around the neck area. This is because, at this time, vigorous bulbs are still so turgid and solid that deeper penetration by the mites between the scales is physically impossible. During August and September, and in fact until replanted, the bulbs gradually lose water and further shrinkage occurs. Large air spaces appear between the bulb scales and the mites gradually work their way into the crevices formed, congregating and breeding in long vertical strips running from the neck to the base of the bulb. These strips appear yellow at first, and then darken to brown as the damaged tissues crack and become callused. During this period the mite population remains comparatively small, and by October or November consists largely of adult females, with males making up only about 5% of the adult population (Hodson, 1934). At no time are eggs and immature stages entirely absent. During the winter, if the bulbs have been returned to the soil the mites become extremely sluggish. However, feeding appears to continue and this contributes to maintaining the bulb in poor condition throughout the winter, with the mites gradually working their way further and further towards the basal region of the bulb.

During the months of January and February the recommencement of root growth results in the bulbs regaining their turgidity. The scales swell and large numbers of mites are crushed between them. Hodson (1934) reported that dead and crushed mites could be found in their hundreds, particulary in comparatively vigourous bulbs

of symmmetrical form where mortality may be almost total, and only those mites inhabiting the neck region escaped disaster. Extensive mortality does not appear to occur in bulbs kept out of the ground at this time and which, as a result, do not become turgid. Nor does high mortality occur in assymmetrical bulbs or bulbs injured by other organisms, even if such bulbs are left in the ground. Bulbs in these categories are, therefore, capable of carrying over, into the spring, much larger mite populations. However, and in apparent contradiction, it has also been found that bulbs left in the ground for two or more consecutive seasons are more severely damaged than similarly infested bulbs which have been lifted and replanted. This is thought to be because bulbs left in the ground remain persistently more turgid than than those lifted and held in store for some weeks or even months. Thus in the former many of the mites always remain in the neck region as they are unable to penetrate deeply between the scales, and therefore considerable numbers persist unchecked throughout the winter and spring.

In early spring the top or neck area of the bulb becomes the focal centre of the infestation as the mites migrate from between the swelling scales. For a considerable part of their development the new leaves are completely encased in thin sheaths, but as the tips approach the tops of the bulbs these sheaths separate. As soon as this separation occurs the mites are able to penetrate slightly into the new growth (Doucette, 1936) and further penetration is possible as the leaves develop. In early spring those mites concentrated in the neck area of the bulb are, therefore, in an ideal position to be ready to attack the new shoots as the sheaths separate. In February, or earlier in some districts, the mites concentrate on the white, fleshy bases of the leaves and flower stems. In this position extensive feeding occurs and under favourable conditions the mites multiply rapidly. This feeding on developing tissues causes the typical streaking and blotching which becomes visible as the foliage grows taller, while at the same time the infestation gradually spreads over the whole of the subterranean portions of the leaves and flowering stems.

Hodson (1934) reports that large numbers of eggs are produced during March and April, but that at that time the mites still tend not to populate the green and exposed parts of the plant. The percentage of males also increases rapidily until, by May, the sexes are present in approximately equal numbers. Wet and cold weather during this period will hamper the increase of the mites, but given warm and dry periods, during May and June, the population will increase extremely rapidly. Hodson states that the female mites now travel up the leaves at night to oviposit, with some, but not all, retiring to cover by day. Large numbers of eggs are frequently laid some inches above soil level, and appear as small dusty patches on the leaves.

During July the foliage withers and the mites concentrate, once more, within the necks of the bulbs where breeding continues on

the upper portions of the fleshy scales. From here they are in a favourable position to move downwards between the scales as the bulb becomes dormant.

## Spread

Hodson (1934) considered that migration between plants took place in early June when, particularly in warm, dull weather, the males and females wander freely over the foliage. As the foliage matures and begins to wilt, a more or less solid mat is formed, at which time distribution of the mites over a whole bed becomes easy.

Doucette (1936) speculated that the only means of spread over long distances was through commercial, or other, transport of infested bulbs by man. He found that, in the vicinity of Puget Sound, on the Pacific North-West of the USA, spread from bulb to bulb in the field was relatively slow. He thought that it would probably be more rapid in warmer climates. In an experiment under cool greenhouse conditions, and using bulbs in shallow wooden trays used for forcing, he found that mites spread from one central infested bulb to all the other bulbs within three weeks. The maximum distance of spread was found to be seven inches. Experiments were also conducted to determine the extent and nature of spread under storage conditions. One infested bulb was used for every five uninfested bulbs, the latter being "heat treated" before the tests. Three months later a sample of five bulbs from each tray was examined and the mites counted. In single-nosed or round bulbs not all bulbs became infested, and those that were infested contained an average of 632 mites. All double-nosed bulbs (i.e. bulbs containing two flowering shoots) were found to be infested and the average number of mites per bulb was 6058. It appears from these experiments that spread of the mite from bulb to bulb whilst in storage is an important factor, as is the nature of the bulb.

Gurney (1966) found that clean bulbs, forced in boxes containing infested bulbs, invariably became infested. However, subsequent spacing experiments, in which infested material was separated from clean bulbs by distances of from zero to two feet of clean soil, showed that infestation occurred only when the separation was less than three inches. Depth experiments, where infested soil was inserted into pots at different depths relative to the planted bulbs, also indicated that infestation was only likely to occur if the "clean" barrier of soil was less than three inches. In respect of this it should be noted that Hodson (1934) states that the mites appear to be able to live for only a very short time when removed from the host plant. Hodson's statement is further supported by the observations of Smith (1935) on *Tarsonemus pallidus* and *T. latus*. Both mite species are phytophagous and a continuing infestation of these mites is wholly dependent upon a continuity of suitable plant growth. If this continuity is broken the mites wll be eliminated. Smith also

found a difference in the distance which could be traversed by the two species. *T. latus* could cross an 18 inch space between plants, while *T. pallidus* did not cross 12 inch gaps. If the foliage of adjacent plants touches then both species spread rapidily as has also been observed for *S. laticeps* (Hodson, 1934).

## The Symptoms of Attack

Dormant *Narcissus* bulbs

Although it is generally thought that there is no way of diagnosing an infestation from the external appearance of the bulb, Hodson (1934) states otherwise. According to him, heavily infested bulbs are recognisable both at the time of lifting and during storage. Such bulbs tend to be abnormally dry, flaccid and light in weight. The dried outer scales, some of which may be incomplete, adhere very tightly to the bulb and are often more numerous than usual.

If an infested bulb is cut through horizontally, small patches of brown tissue can be clearly seen, particularly at the angular points of the scales. Large numbers of mites may also be visible in the neck regions. If the bulb scales are pulled apart, the brown or yellow marks can be seen extending downwards, as long narrow scars, from the apex to the extreme base of the individual scales. Mites can, however, be found in bulbs with no visible signs of damage. Soft, open bulbs with large air spaces tend to be more heavily infested than firm, solid bulbs.

Forced *Narcissus* bulbs

Infested bulbs, which have been forced, exhibit the most serious and obvious signs of damage, often resulting in considerable reduction in the yield and quality of the flowers.

Immediately a bulb infested with bulb scale mites is subjected, to the abnormally high temperatures used during forcing, a rapid increase in the mite population occurs. In a very short period large numbers of mites congregate in the neck region of the bulb and intense feeding takes place. Under these conditions the mites become easily visible to the naked eye as a greyish dust at the base of the leaves. Later, the flower buds become similarly covered in mites, and eventually mites can be seen freely distributed all over the foliage. Eggs are deposited many inches above ground level on both the upper and under surfaces of the leaves, although, according to Hodson (1934), those laid in very exposed sites rarely hatch. The most obvious symptom of attack is the abnormally green colour of the foliage. This is largely due to the loss of the leaf "bloom", probably because of a reduction in wax on the leaf surface. The leaves eventually

become distorted and sickle-shaped, while the leaf edges are scarred giving a "saw-edge" effect. In addition, injury caused by the mites feeding may cause yellow flecking of the leaves, a condition difficult to distinguish from a virus disease of *Narcissus* known as "Yellow Stripe". It is also typical to find lunate areas, which are abnormally light in colour, situated about half an inch below the tip of at least the two innermost pairs of leaves. These marks are made by those mites which congregate at these points almost immediately upon the bulbs first being subjected to artifical heat.

The effect of an infestation on the flowers from forced bulbs can be even more disastrous. The congregation of the mites at the neck of the bulb coincides with the time at which the flower bud is being protruded, and it is at this stage in the growth of the bulb that it is normally taken into the forcing house. As a result extensive injury is caused to the flower bud. In extreme cases both the flower bud and stem are killed. In a less severe infestation the bud may be killed but the stem bearing it continues to grow, or the flower buds may not be killed but produce weak, imperfect and inferior flowers.

Outdoor *Narcissus* bulbs

Although the symptoms are far less severe in bulbs grown in the open, *S. laticeps* infestation still has a serious long term cumulative effect. Narcissi being early spring flowers, the vigorous growth takes place while temperatures are too low to promote a rapid increase of the mite population. During the winter, in bulbs remaining in the ground, this population is relatively small. It is therefore usual for infested bulbs to produce comparatively normal growth up to and during the time of flowering. Sometimes, however, when the weather in late winter or early spring has been exceptionally mild, symptoms of damage are more obvious and in warmer areas can be quite severe.

Outdoor plants grow more slowly and feeding marks, visible as yellow streaks, and blotches often streaked with brown, become evident on the lower regions of both foliage and flower stems. These feeding marks become more evident in April and May as the temperature rises, and the mite population rapidly increases. These activities may cause premature wilting and death of leaves and consequently effect the amount of food stored within the bulb. Ultimately this results in a reduction in the size of the bulb.

Because plant growth is slower outdoors, the mites concentrate upon the young leaves before the flower buds have made any appreciable growth. In extreme cases leaf growth may be entirely inhibited, while the flower stem emerges intact and produces a small and, usually, imperfect bloom. Such infested stocks may be almost entirely destroyed during a prolonged spell of weather favourable to the mites.

*Hippeastrum* (Amaryllis)

Blattny (1933) reported that the "Red Burner" (*Roter Brenner*) disease of Amaryllis was caused by a Tarsonemid mite which was described by Dr Storkan of Prague as almost certainly identical with *T. hydrocephalus* ( = *Steneotarsonemus laticeps*). The mite was first noted by Blattny in 1930 in a glasshouse in mid-Bohemia (Blattny, 1933). As a result of innoculation experiments he became convinced that *T. hydrocephalus* was a primary pest of Amaryllis, and he described a number of experiments in which he successfully bred the mites in sound bulbs. The mites he placed in the healthy bulbs increased in numbers and typical "Red Burn" symptoms appeared in three months. He observed that the first indication of mite infestation is that reddish streaks and spots appear on the elongating leaves. This reddening is intensified on the upper part of both sides of the bulb scales and may extend down into the bulb for some distance. These reddish lesions elongate as growth increases and may ultimately constitute a scar several inches in length.

Blattny also reported that in severe infestations the flowers shrivel or the flower stems remain short, and the original surface lesions become deeper and shrivelled. The leaves and stems are poorly developed, and finally the entire bulb may decompose since secondary agents such as the Bulb Mite (*Rhizoglyphus echinopus*), bacteria and fungi may follow the primary attack of the Tarsonemid. He further states that confident diagnosis of Tarsonemid mite attack is difficult unless the mites themselves are found, as almost any form of injury to Amaryllis causes the "Red Burn" symptoms.

Fox-Wilson (1939) conducted similar innoculation experiments on Amaryllis and agreed that most forms of injury to these bulbs give rise to a reddening of the attacked tissue. However it was his opinion that the Tarsonemid mites give rise to a reddening of the leaf tissues only before they emerge from the bulb. In Fox-Wilson's innocuation experiments there was a shorter period between the time of artificially infesting the bulbs and that when the first signs of attack became apparent. Typical reddish streaks were noted thirteen days after the innoculation was made, compared to three months in Blattny's experiments. He also observed that although there were similarities between the symptoms noted by Hodson (1934) in *Narcissus* and his own experiences with Amaryllis, they were accentuated in the latter bulbs due to the brilliancy of the reddening on the attacked surfaces. As in *Narcissus* bulbs there was a very rapid increase in the mite population chiefly in the neck region of the Amaryllis bulb. Unlike the situation in *Narcissus*, large populations of mites were not observed on the exposed leaf surfaces. However, Labanowski *et al* (1990) state that during the growth of *Hippeastrum* in Poland the number of mites increases very quickly and they frequently spread from the neck of the bulb onto the leaves and flowers, where the females lay their eggs. As a result the leaves and stem become distorted, stem growth is inhibited

and the flower is usually poorly developed.

## The role of *S. laticeps* in the transmission of "Narcissus Smoulder"

Gray, Shaw and Shiels (1975), while recording the progress of rotting produced by smoulder in *Narcissus* bulbs grown in Scotland, observed that many of the lesions were located at the angles of the white scale of the senescent second leaf, a position where *S. laticeps* tends to congregate. Although their observations were not entirely conclusive, they thought that the negligible amount of smoulder in one particular year's crop could be attributed to the use that year of hot water treatment to control *S. laticeps*.

Gray and Shiel (1987) carried out some experiments in order to establish the role of the mites in Narcissus smoulder transmission. They stated that the curling of leaves due to "smoulder" resembles the distortion caused by *S. laticeps* in forced Narcissi and they observed the mites moving large detached clumps of smoulder mycelium from the brown tissue in the neck of the bulbs to adjacent white storage scales. In every instance observed the areas of storage scale affected by smoulder, and extending down from the neck , originated on the yellow lines where the mites had fed and not on the white tissue. The abnormally bright colour resulting from the loss of 'bloom' on the surface of leaves is symptomatic of mite feeding damage. When examined under a scanning electron microscope there were indications that the wax covering normally present of the leaves was less complete or less uniform on leaves lacking 'bloom'. In innocuation experiments, leaves, with reduced 'bloom' and evidence of mite feeding, were infected by smoulder. Leaves with normal 'bloom' became infected only after the epidermis was damaged by scraping. The authors concluded that *S. laticeps* causes damage which results in infection with smoulder, and that there was a clear association between the mite and smoulder symptoms.

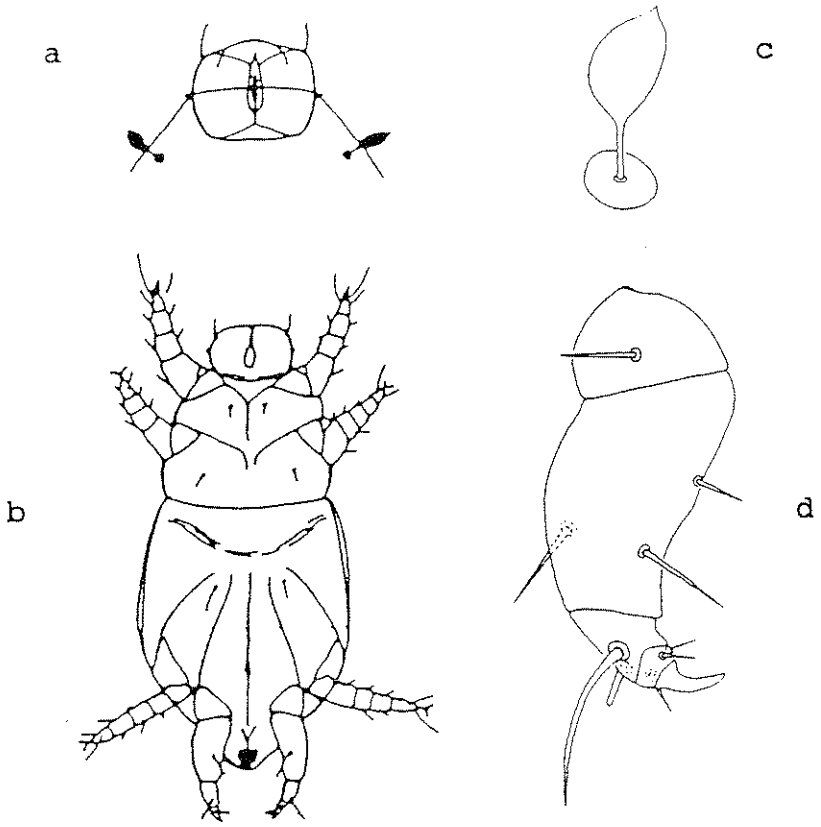
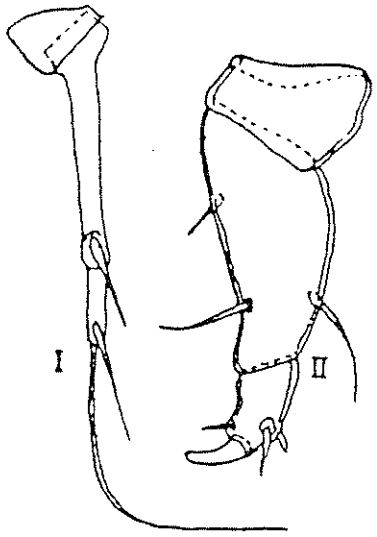


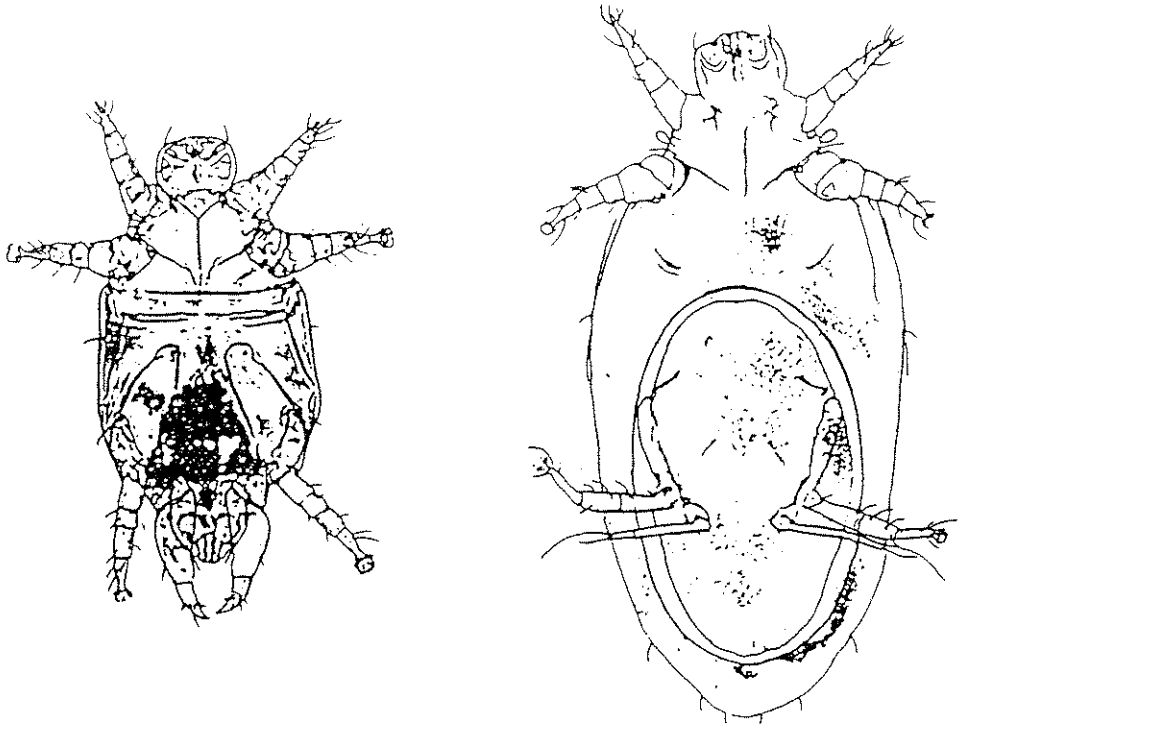

**Figure 1** a) gnathosoma & pseudostigmatic organs b) male
c) pseudostigmatic organ d) male leg IV

a) & b) from Halbert (1923) c) & d) from Beer (1954)




*Tarsonemus approximatus* Bks. var. *narcissi* Ewing. × about 610.
I. Right leg iv. of ♀ from below.
II. Left leg iv. of ♂ from below.

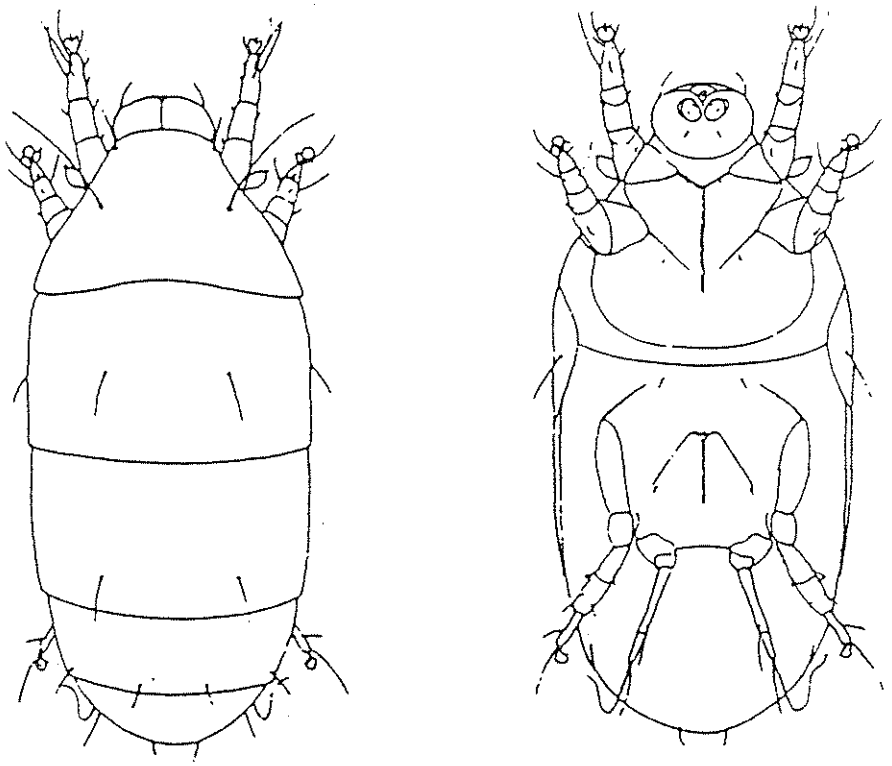
**Figure 2** From Massee (1933)



*T. approximatus* var. *narcissi*, adult (greatly enlarged).

*T. approximatus* var. *narcissi*, adult ♀ showing egg within the body (greatly enlarged).

**Figure 3** From Hodson (1934)



*Tarsonemus hydrocephalus* n. sp.
♀, die Rückenseite. ♀, die Bauchseite.

**Figure 4** From Vitzthum (1929)

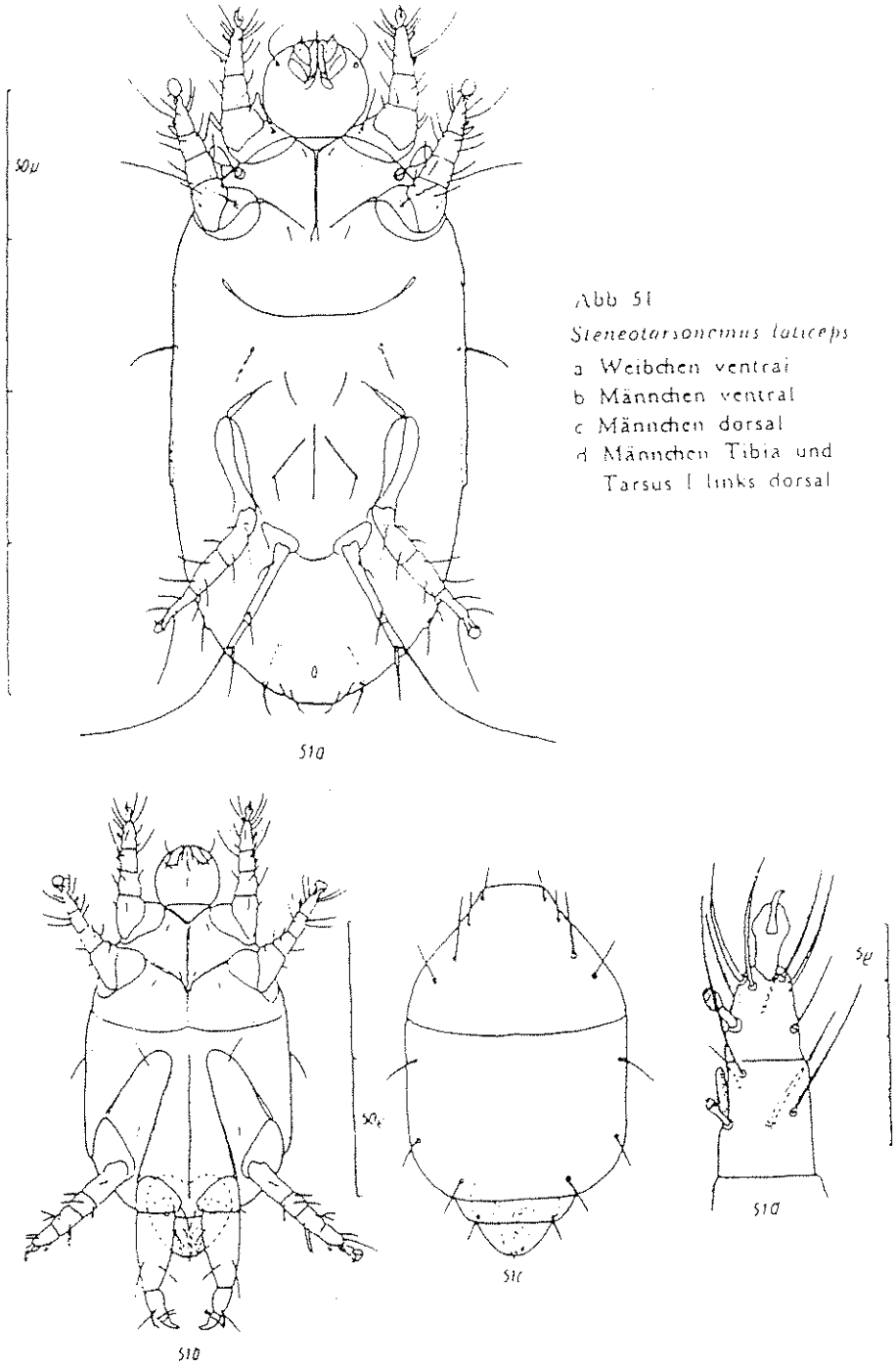


Abb 51
*Steneotarsonemus laticeps*
a Weibchen ventral
b Männchen ventral
c Männchen dorsal
d Männchen Tibia und Tarsus I links dorsal

**Figure 5** *Steneotarsonemus laticeps*
a) female ventral view
b) male ventral view
c) male dorsal view
d) male tibia and left tarsus I dorsal view

(From Stammer, H.J. 1959. *Mitteleupaischer Acarina. Band I Tyroglyphidae und Tarsonemini*. pp. 713-823. Akademische Verlagsgesellschaft, Leipzig.)

## PART 2 - CONTROL

### Control Measures

Regular inspection of bulbs for forcing

Regular inspections of stocks are extremeely important in minimising losses due to mite damage. If an infestation is discovered at an early stage, or before it has time to develop into a serious problem, the most appropriate treatment for that stage can be applied.

During inspections healthy bulbs should be firm and solid. Bulbs which are undersized, or unusually soft, should be inspected more closely for signs of infestation. This can be checked for by cutting open a sample of suspect bulbs and looking for the characteristic symptoms of damage (i.e. yellow or brown horizontal streaks). If these are not in evidence, as is sometimes the case, but the bulbs are still suspect, then examination of a sample from between scales, particularly from the neck area, with the aid of a binocular microscope will prove effective. Heavily infested stocks should be discarded immediately, but lightly infested batches will still give a useful yield of saleable flowers if treated chemically soon after housing for forcing.

Hot Water Treatments

This is simply the immersion of the bulbs in water hot enough to kill the mites inside the bulb over a given period of time, without damaging the bulb itself.

The earliest published record of hot-water treatment as applied to Amaryllis bulbs was by Saunders (1890) who suggested sterilising the soil the plants were growing in and immersing the bulbs in hot water at 125 F (51.7°C) for ten minutes. This treatment was for the externally occurring Bulb Mite, *Rhizoglyphus echinopus*. This period of immersion is too short to achieve a high mortality of *S. laticeps* which lives inside the bulb.

Over the next few years there were a number of experiments with different immersion time and temperature combinations. Another variable frequently examined was the best time of year to carry out the treatment. Blattny (1933) suggested 30 minutes at 40°C before the winter rest period. Hodson (1934) stated that one hour at 43.3°C resulted in 100% kill of *S. laticeps*. He also stated that if bulb were treated annually after lifting, a high and adequate measure of control would be achieved. However, he acknowledged that this is not always practical, especially in stocks needed for forcing or immediate sale, and suggested a biennial treatment as a compromise.

Winfield (1958) believed that while hot water treatment for one

hour at 43.3°C would kill most of the active stages and eggs, it would not effect complete eradication. He recommended four hours at 43.3°C or three hours at 44.4°C. If the bulbs are to be forced during the season immediately following treatment then a good crop of flowers may be taken, with least risk of loss of bloom due to the treatment, if a treatment of 43.3°C for one hour is used. However if the stock is intended for growing on outdoors he thought it necessary to increase the time, or raise the temperature, of the treatment. Winfield also observed that a cool dip of 0.2% thionazin, at 18.3°C, with 0.1% of a non-ionic wetting agent gave a similar degree of control to hot water treatment at 43.9°C for three hours.

Doucette (1936) found that $1^1/_2$ hours at 43.4°C was sufficient to kill all stages. He also stated that vapour heat treatment would also effect complete mortality in two hours at 43.3°C - 43.9°C. This entails the bulbs being heated by super-saturated warmed air which is circulated through the bulbs stacked in trays, and which is maintained at the desired temperature by steam and water sprays. Spruijt and Blanton (1933) found that *Narcissus* bulbs which had been vapour-heat treated at 120°F (48.9°C) for two hours produced flowers equal to those of untreated controls, and that the foliage was not injured by this treatment. However, as Doucette pointed out, in both methods the period of treatment is exclusive of the time required for the bulb to reach the treatment temperature. Gibson (1927) observed that the standard treatment of three hours immersion at a temperature of 110°F (43.3°C) is not necessarily the same thing as three hours in the tank. The temperature of the water falls when the bulbs are put in and it may take as much as half an hour to regain the correct temperature. Staniland (1933) points out that the size of the bulbs is important. In larger bulbs, placed in water at 110°C, initial heating to a temperature of 108 C in the centre of the bulb is very rapid. The rate of heating then becomes very slow. This diminishing rate of heating, as the water temperature is reached, also occurs in smaller bulbs, but is much less marked.

Hot water treatment for three or four hours, according to bulb size, was originally developed to control eelworm infection of *Narcissus* (Horton, 1958). As can be seen above there appears to be some dispute as to whether this length of time is necessary in the case of the *S. laticeps*. Some authors believe that one hour is sufficient and others, maybe erring on the side of safety, opt for a longer period. The ultimate fate of the bulbs will often affect this decision (e.g. Whether they are to be forced or planted out.). The hot water treatment sometimes damages the blooms of bulbs that are forced and the shorter period of treatment is often recommended in this instance (see, for example, Winfield, 1958). However Wallis (1967) and Anon. (1986) state that warm storage of bulbs immediately before hot water treatment considerably reduces all forms of bulb damage caused by the treatment. It also enhances growth and flowering during the final year; the advantages of this improved growth are often still evident in the second season.

The effect of warm storage appears to be associated with the metabolism of the bulb. The rate of respiration, of bulbs stored in this way, slows down at the growing point and makes the devoloping flower, leaf and root more tolerant of the hot water treatment. In warm seasons the heat required for bulbs to achieve this condition is acquired naturally and the the bulbs reach the most resistant stage by July-August. This is from four to six weeks after lifting, and when the flowers of most varieties are fully formed. Ideally the safest time for minimum leaf, flower and root damage by hot water treatment is shortly after the bulbs have completely formed the flower initials (Anon., 1977). There is some variation between varieties, localities and seasons, but for the main varieties the safest time in the south-west is mid-July and for the eastern counties it is late July to mid-August. The end of the hot water treatment season is determined by the date at which active root growth starts, although Doucette (1926) succeeded in treating *Narcissus* bulbs, with new roots two to three inches long, with no apparent adverse effects. These bulbs were kept wrapped in moist cheesecloth after treatment and until planted out.

Following hot water treatment, it is extremely important to prevent reinfestation. Strict attention must be given to hygiene as contamination during storage is often the main source of reinfestation. Hodson (1934) stated that in the absence of the host plant the mites will rapidly die. Therefore reinfestation of treated bulbs is unlikely unless they are placed immediately adjacent to heavily infested ones. It is important that storage facilities are kept clean and sterile and that, before planting out, the ground is cleared of self-set bulbs.

## Chemical Control

A serious *S. laticeps* 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. In these circumstances some form of chemical control may be necessary. In the example of infested forcing bulbs some form of treatment is a matter of extreme urgency before the mite populations have built up to a sufficient level to jeopardise the flower crop. Treatment at this stage is very difficult, especially with chemicals, as many of the mites remain safely inside the bulb and are not easily accessible. Over the years a number of trials of chemical treatments have been carried out with varying degrees of success.

Hodson (1934, 1948) stated that partial and temporary control could be achieved by a thorough spraying with a 1% white-oil emulsion. The spray must be directed well into the centre of the plants, and is most effective if carried out just as the flower buds appear (i.e. Very soon after the bulbs are subjected to

heat.). This usually ensures the saving of a high proportion of the blooms, but it is only a temporary measure. Bulbs to be retained after forcing must be subjected to hot water treatment before replanting.

Harrison (1956) tested a number of systemic insecticides on heavily infested *Narcissus* bulbs intended for forcing. In the first trials applications of fluoracetamide, schradan, dimefox and mipafox were carried out on the bulbs just before they were brought into the glasshouse. The results demonstrated a significant increase ($P<0.05\%$) in the number of marketable flowers produced with all treatments except mipafox. Mipafox damaged the bulbs at the concentration used. The experiments were repeated a year later using fluoracetanilide, schradan and amiton. Dimefox and mipafox were not used, because of the toxic hazard of using dimefox under glasshouse conditions and because of the severe injury caused to the bulbs by mipafox. The results from this second trial were inconclusive because although 95% of the bulbs were infested the total number of mites present was too small to give a clear indication of the effectiveness of the treatment. Harrison pointed out that fluoracetanilide and amiton are both highly toxic and that their general use by growers was not recommended.

Collingwood (1959) carried out similar trials with fluoracetamide, endrin and demeton-S-methyl, as well as with a frost treatment. In each case, at the end of the trial a high proportion of the bulbs contained mites. However, there was almost total suppression of feeding on the foliage in the endrin treated bulbs, and the growth was vigorous and clean. The frost treatment did not reduce the mite populations although the foliage growth was more vigorous than in the control bulbs. Demeton-S-methyl resulted in increased damage and larger populations of mites. This was possibly due to the destruction of springtails and predatory mites, which were present in some numbers in the controls. In the absence of a method of assessing the mite population, within the bulb both Harrison (1956) and Collingwood (1959) used flower production and damage to assess the effects of the pesticide used.

Winfield (1964) tested a number of acaricidal drenches on *Narcissus* plants, infested with *S. laticeps*, soon after the bulbs were brought indoors for forcing during January and February. The experiments were an attempt to test the effect of these drenches under commercial conditions, and were carried out in 1960, 1961 and 1963. The chemicals used were endrin, azinphos-methyl and endosulfan drenches, which were applied with a fine-rose watering can or with a knapsack sprayer at similar volumes per unit area. All the drenches included a 0.1% succinate wetter.

In the 1960-61 experiments, mite populations on foliage were assessed by direct examination under a low power dissecting microscope, but this method was felt to be too subjective,

relying heavily for its success on the skill and patience of the observer. In the 1963 experiments a technique for washing the mites off the leaves was developed and compared with the direct observation method. It was found that the direct observation disclosed only 15-20% of the mites actually present on the leaves, and that the results obtained by the same operator were fairly consistent for both direct observation and washing.

The results of the acaricide tests showed that endrin consistently gave a good control of mites and eggs on foliage; endosulfan also gave a good initial control of the mites but was not so persistent as endrin. Azinophos-methyl was less effective than the other two compounds, and as the experiment progressed there was an increase in the number of mites on the foliage. It was thought that this may have been due to azinophos-methyl killing the natural predators as was suggested for demeton-S-methyl (Collingwood, 1959).

In the 1960 experiments chemical treatment increased the number of first quality marketable blooms and gave a good cash return, but in 1961 the yield was depressed in two separate experiments. In 1963, treatment raised the quality and increased the proportion of the flower crop which was harvested early. However Winfield believed that these toxic materials should only be used under glass in exceptional circumstances.

Winfield (1971) carried out some further experiments in which bulbs infested with both *S. laticeps* and the stem nematode, *Ditylenehus dipsaci* (Kuhn) were given either one or two hour treatments in water at 44.4°C, or in 0.23% thionazin solution at ambient temperature. All treatments controlled both *S. laticeps* and *D. dipsaci*, and growth and flowering during forcing were normal. The bulbs were then grown outdoors for two years, but only those that had been hot water treated (at 44.4°C for three hours), after forcing, maintained or slightly increased their planting weight. Bulbs which were not hot water treated after forcing survived poorly due to nematode damage. *S. laticeps* was controlled by treatments that were inadequate for *D. dipsaci*.

As a result of reports of severe infestations of *S. laticeps* on field-grown bulbs from Norfolk, Gurney (1970) carried out some trials to find an effective systemic insecticide. Infested bulbs were grown in compost treated with granular formulations (5ppm and 20 ppm active ingredient) of aldicarb, phorate, thionazin and fonofos. Preliminary results showed that only aldicarb at 20 ppm prevented contamination of the foliage of forced bulbs. The bulbs used were grown for a second year (Gurney, 1971). It was concluded that none of the materials used was effective. Further experiments (Gurney, 1972) showed that, irrespective of the stage of growth at the time of treatment, *Narcissus* bulbs do not translocate systemic pesticides either upwards from the root or downwards from the leaves.

Wilkin *et al* (1976) carried out some field and laboratory trials

on the effects of the acaricides phoxim and pirimiphos-methyl on the control of *S. laticeps*. Infested bulbs were soaked in 0.5% phoxim or pirimiphos-methyl for two hours. After treatment the bulbs were allowed to dry and were then stored in plastic nets at ambient conditions in the laboratory. An untreated control batch was stored in the same way. No pre-treatment counts of mites were made. Fourteen days after the treatment five bulbs were selected from each batch and examined for mites. Some of the remaining bulbs were planted and allowed to grow at ambient condtions for eight months when they were examined for mites.

In the laboratory trial only one live mite was found on the bulbs treated with phoxim and very few were found on those treated with pirimiphos-methyl. It is not quite clear whether or not this result refers also to those bulbs grown on for another eight months. The control batches were found to contain heavy infestations of *S. laticeps*.

During field trials infested *Narcissus* bulbs growing in a field in Norfolk were sprayed with pirimiphos-methyl or phoxim at the rate of 1.5 pints a.i/100 gallons water/acre. This treatment was applied in April during flowering. The bulbs were examined for mites five weeks after the treatment and again when the bulbs were lifted after flowering. The results of these field trials are difficult to interpret but it is apparent that the field treatment did not achieve as effective a control as the laboratory treatment. The author suggests the method of field application may have led to the bulbs receiving a low dose of the acaricides.

At present it appears that endosulfan is the only acaricidal compound available in the UK, under the Control of Pesticides Regulations 1986, for use in controlling *S. laticeps* (see Ivens, 1993). Application of a drench of 0.1% endosulfan plus wetter would appear to be the currently recommended procedure (Anon., 1984a, b) for bulbs found to be infested when brought in for forcing. The 0.1% drench (500 ml of 20% emulsifiable concentrate in 100 l of water or 4 pints in 100 gallons) plus an efficient wetter, should be applied within a few days of bringing the bulbs indoors. Frozen boxes should be allowed to thaw out before treatment. The drench should be applied by means of a watering can with a fine rose, or by using a knapsack sprayer working at low pressure, at an application rate of 2.75 l/m² (1 gallon/2 square yards) of actual bulb area. The drench should be directed towards the centre of the plants and the foliage should be thoroughly wetted. This treatment will give only partial control because many mites will still be inside the bulb where the chemical cannot reach. It will however check the mite populations sufficiently to allow foliage and flowers a chance to emerge with minimal damage.

Fumigation

A large proportion of the UK bulb production is exported (Powell, 1977) and for this, clean, healthy bulbs are required. A quick method of disinfestation which could be used safely at any time during the storage period would be an asset to growers and exporters. A technique which does not involve wetting the bulbs would also be an advantage and would facilitate both handling of clean stocks before forcing and packing for the export trade (Gurney and Gandy, 1974). The possibility of the fumigation of bulbs has, therefore, been investigated by several workers.

Mackie *et al* (1942) claimed that their methyl bromide treatment at 48 g/m$^3$ for 2$^1/_2$ hours (concentration x time product (ct-product) = 120 gh/m$^3$) would kill *S. laticeps* at temperatures between 15°C and 21° C, and that treatment time could be reduced to 1$^1/_2$ hours above 21° C. They found, however, that the treatment must be repeated after 10-14 days because the eggs survived. The FAO Manual (Monroe, 1969) also recommends a repeat treatment to prevent population build-up during storage. This repeat treatment is at the same dose, time and temperature as the initial treatment.

The Dutch authorities have recommended fumigation since 1969 and the technique was confirmed by EPPO (European Plant Protection Organisation) in 1974 (Anon., 1974). The technique involves fumigation with methyl bromide using a large initial dose, (almost twice that recommended by Monroe 1969), and short exposure time. The treatments recommended by EPPO are 85 g/m$^3$ for 3 hours at 10-15°C and 85 g/m$^3$ for 2 hours at more than 15°C. Beijer and Bergman (1970) stated that treatment at 55 g/m$^3$ for 4$^1/_2$ at 15°C and 21°C immediately before planting appeared promising.

Whilst controlling mites, the concentrations of fumigant used may damage the bulbs and several authors have investigated fumigant use from this point of view. Breakey (1943) monitored the effect of fumigation on Narcissus, Iris and Lily bulbs. Methyl bromide was applied at a rate of 2lb (32 g/m$^3$) for 2, 2$^1/_2$ and 3 hours, and at 3lb (48 g/m$^3$) for 2, 2$^1/_2$, 3 and 4 hours. Cyanide fumigation was also carried out. All treatments were carried out at 70°F (21.1°C). Only the higher concentrations had any appreciable effect on the growth and development of the *Narcissus* variety used, but the effects were more pronounced on the other bulbs. The treatment of 2lb (32 g/m$^3$) methyl bromide for 2$^1/_2$ hours gave the optimum results. Andison and Cram (1952), working on bulb fly control, demonstrated that 48 g/m$^3$ of methyl bromide did not damage three varieties of *Narcissus* when they were exposed for up to 4$^1/_2$ hours at between 15°C and 21°C (ct-product of 216). Purnell and Hague (1965), working on nematodes, showed that *Narcissus* bulbs were damaged at ct-products above 560 and Thomas (1965) confirmed that a ct-product of 500 was the highest rate tolerated by the varieties, King Alfred, Golden Harvest and Helio.

In view of the promise shown by fumigation, Gurney and Gandy (1974) made further trials during the 1972-73 season. In small scale trials, heavily infested *Narcissus* bulbs, which had been lifted and stored for at least two months, were treated with methyl bromide over a range of ct-product values from 102 to 251 (38-118 g/m$^3$) at temperatures between 19°C and 24°C for for times of 1 - 4 hours. Bulbs were exposed in the open air for 24 hours after treatment in order to allow the gas time to disperse. A quarter of the treated bulbs were sampled at 1, 7 and 14 days after treatment; their scales were dissected out and examined for mites and eggs. The other three-quarters of the treated bulbs were potted out for six weeks, during which time there was no sign of damage or delayed growth. All the bulbs were then forced in a heated greenhouse, together with the untreated controls. Samples of the forced treated and untreated bulbs were examined for mites and eggs when the foliage was 150 - 180 mm high and the flower bud just visible.

No living mites were found, nor did any eggs hatch during the fourteen day period in which the bulbs were dissected after treatment. The forced, fumigated bulbs also remained healthy and mite-free, apart from slight feeding damage to the leaf tip and caused by the mites feeding before treatment. All mites on the scales dissected from the forced treated bulbs were dead and there was no evidence of egg survival or hatch. Earlier workers had concluded that mite eggs survived fumigation and that, therefore, repeated treatments were necessary to effect control. The mites and eggs that Gurney and Gandy found killed by the methyl bromide remained plump and healthy looking in the humid conditions between the bulb scales. However, microscopic examination showed them to be dead. The method of washing mites from the tissues was not used as it would have been impossible to determine whether the mites were killed before or during extraction. There were no apparent phytotoxic effects and the growth of the bulbs was normal. The untreated bulbs showed high levels of infestation with vast numbers of mite swarming and egg-laying on their damaged leaves.

Gurney and Gandy (1974) concluded that fumigation by methyl bromide was a practicable and viable method for the control of *S. laticeps*, and that the minimal pretreatment mite damage reported during the experiments could be avoided if the bulbs were treated as soon as possible after lifting. Reinfestation could be avoided if suitable hygiene practices were observed, i.e. immediate disposal of waste material and badly damaged bulbs, the sterilisation of vehicles and containers before use and the separate storage of treated and untreated stocks.

Murdoch (1975) made weekly examinations, until mid-October, of unplanted dry bulbs which had been commercially fumigated in mid-September. There appeared to have been a total kill of mites and eggs, but 42% of the flowers produced were of second class quality and by cropping time 52% of the bulbs had become

reinfested. He gives no details of the fumigation or experimental methodology for this trial, but goes on to state that a further four cultivars were treated commercially, with apparent success, during 1972 at a ct-product of 200 and at a cost of £200 per ton.

During 1973-74 methyl bromide fumigations at ct-products of 250 and 500 were carried out on six *Narcissus* cultivars in early September. Assessment of mite and egg infestations in the dry bulbs was made before, and after, treatment. Initially between 40 and 100% of the pretreatment bulbs were found to be infested. Post treatment examination of unplanted dry bulbs at monthly intervals, up to December, indicated survival only in one cultivar treated at a ct-product of 250 and in one treated at a ct-product of 500. However, examination of the bulbs during forcing indicated infestations in all cultivars at both rates of treatment, although individual comparisons indicated a 90% reduction in mite numbers in five of the cultivars where treatment had been at a ct-product of 250, and a 57% reduction in the sixth cultivar. In three out of the four cultivars treated at a ct-product of 500 there was an 80% reduction, but in the fourth there was a 48% increase in numbers. Infestations in untreated stock during forcing varied between 0.5 and 74.8 mites and eggs per gramme of stem. One stock of bulbs affected by basal rot was apparently killed at a ct-product of 250. The latter treatment had little effect on the percentage of marketable flowers produced, when compared with untreated stocks. However treatment at a ct-product of 500 reduced the marketable number of flowers by 87%, 69%, 43% and 24% in the four cultivars, compared with an 84-99% performance of untreated stocks of these cultivars.

Murdoch (1975) states that during the bulbs period on the standing ground prior to forcing they were subject to unusually severe frosts which may have reduced the mite populations in all stocks and therefore affected the performance of both treated and untreated bulbs and mites. However he concludes that methyl bromide fumigation at a ct-product of 200-250 is both cheap and adequatelly effective in controlling *S. laticeps* in *Narcissus* bulbs destined for export.

In the light of the EPPO recommendation (Anon., 1974) on the use of methyl bromide fumigation, Powell (1977) carried out a number of experiments to test the effects of fumigation at 18°C on both *S. laticeps* and *Narcissus* bulbs. In the first, a severely infested cultivar was treated, during the storage season, with commercial methyl bromide (containing 2% chloropicnin) at ct-products of 130, 172, 215 and 260 gh/$m^3$, i.e. 43 g/$m^3$ for approximately 3,4,5 and 6 hours. These were compared with the EPPO treatment. Before treatment, one day after treatment and then at ten day intervals, mite numbers were assessed by dissection and microscopic examination, and by a washing extraction technique. Mites were considered to be alive if they showed limb movement, and eggs were considered to be alive if they were still turgid. Only the two lowest doses failed to kill

all the mites. At a ct-product of 130 gh/m³ a few mites were seen on the first count and numbers gradually increased in later counts as eggs hatched. At a ct-product of 172 g.h/m³ a few live mites were seen on the first count and none subsequently.

Mite numbers were also monitored, over two seasons, on infested bulbs treated at ct-products of 200 and 250 gh/m³. During the first season bulbs were treated at one of three times - early storage (late July), mid-storage (September) and late storage (late October) - in order to see if treatment time affected the population size. Mite numbers were assessed before the first season's treatment, immediately after lifting at the end of the first growing season, and after four months storage following the second growing season. All the treatments reduced the mite population, but none gave complete control. Powell considered that late treatments were generally less effective than those at early or mid-storage, but the differences were not significant. In untreated bulbs infestations built-up each season.

Powell (1977) also carried out three tests in order to assess the phytotoxicity of methyl bromide on the bulbs. In the first, infested bulbs, fumigated in October with a range of doses from ct-product 130 to 340 gh/m³, were monitored for damage to the foliage and flowers during the following growing season. All of the bulbs performed at least as well as unfumigated bulbs, with the exception of those treated at the ct-product of 340. These produced stunted foliage and very few flowers.

A comparison of the effect of time of fumigation on phytotoxicity was carried out at the same time as the comparisons of mite populations, and using the same bulbs, fumigation times and techniques. Following fumigation the bulbs were 'aired' for 1-2 weeks before being planted out in a plot which had been disinfected with dichloropropane-dichloropropene at least six weeks before planting, and rotivated two and three days before planting to ensure good aeration and dispersal of any residual fumigant. Before planting the condition of the bulbs was checked, and only sound bulbs were planted. Flower production and foliage damage were monitored over the growing season, as were the weight and condition of the bulbs after lifting, cleaning and drying for storage. Bulbs planted after treatment at the ct-product of 200 gh/m³ showed no significant differences in their response to early, mid or late treatment times, nor were there any significant differences between treatments and controls. Untreated bulbs which had ben grown outdoors were kept and replanted for a further season following a further fumigation with 50 g/m³ (ct-product = 250 gh/m³) in order to test the proposed EPPO recommendation (Anon., 1974) None of these bulbs showed any significant differences in relation to phytotoxicity.

From these experiments Powell concluded that methyl bromide treatment of bulbs was a useful form of control which could be applied at any time during storage without harming the bulbs. However complete control was not always possible at methyl

bromide concentrations which would not damage the bulbs, and mite populations were capable of increasing between treatments. He believed that these findings disagreed with those of Gurney and Gandy (1974) who found smaller doses to be completely effective and while the EPPO method (Anon., 1974) was effective, he felt that it could be improved by a small increase in dosage and longer exposure time. As mites increase with storage time, he advised early treatment and belived that a ct-product of 250 gh/$m^3$ at 15-20°C would ensure reasonable gas concentration. Below 15°C this dose or exposure time may not be sufficient, and above 20°C there is a possibility of greater phytotoxic risk. Fumigation is of particular value in bulbs intended for forcing as it prevents a build up in population size and the damage this would cause during the forcing process.

Anon. (1984a) recommends treatment between 200 and 250 gh/$m^3$ at a temperature between 18°C and 20°C. The leaflet also points out that the major disadvantage of fumigation is the dangerous nature of methyl bromide and the need for expert handling of the substance. In view of this fumigation should only be carried out by specialist contractors. Anon. (1984b) also recommends methyl bromide fumigation of the peat in which the bulbs were forced, if this peat is to be reused.

Protection of Treated Bulbs

Numerous authors emphasise the importance of hygiene following the treatment of bulbs to control *S. laticeps*. Bulbs, treated by any of the methods discussed above, must be kept isolated from untreated stock. Anon. (1984a) recommends that boxes and pallets used to carry untreated stocks must be dipped in cresylic acid (500 ml of 40% cresylic acid in 50 l of water). Vehicles used for transporting stock must be thoroughly cleaned and all possible areas of cross-contamination must be avoided. Treated stocks are best planted without delay into land which has not recently carried a *Narcissus* crop.

Biological Control - Natural Enemies

Few observations have been reported of the predators and other natural enemies of Tarsonemid mites (Lindquist, 1986) and none at all of those, if they exist, of *S. laticeps*. Tarsonemid mites are so small as probably to be beyond the scope of prey for many arthropod predators, although they are undoubtedly subject to predation by some of the smaller insects and by various predatory mites. Cheyletid mites (Mcgregor, 1942; 1944) and Phytoseid mites (Guitierrez, 1968; Lo & Ho, 1979) have been observed actively feeding on Tarsonemids.

One Phytoseid species, *Amblyeius cucumeris* (Oudemans), commonly used for the control of thrips, feeds preferentially on *P. pallidus* on strawberries in California (Huffaker and Kennett, 1956). Recent laboratory studies by McMurty *et al* (1984)

indicate that four Phytoseid species prey readily on *P. latus* and show promise for the biological control of this pest in Californian lemon orchards. *Phytoseiulus persimilis* Artias-Henriot is thought to reduce economic damage by *P. pallidus* to strawberries under field conditions (Simmonds, 1970).

As *S. laticeps* spends a large proportion of its life history between the scales of the bulb it tends to be inaccessible to larger predatory mite species. However during the growing season they migrate, lay their eggs and continue their life cycle on the flowers and leaves of *Narcissus* often building up into very large numbers (Hodson, 1934). It may well be possible to introduce a suitably efficient predator at this stage in order to control the population on the aerial parts of the plant and consequently reduce damage. If successful, this would also reduce the residual population available to reinfest the bulbs during the winter months.

Little is known about pathogenic organisms associated with Tarsonemid mites. Lo & Ho (1979) observed spores of a micro-organism that infested and killed all stages of the Rice Tarsonemid, *Steneotarsonemus spinki* Smiley, and which parasitised 60 - 70% of the mite population during two successive years monitoring. There are other fungi and pathogens which appear to be lethal and specific to mites. However, again the problem would be the inaccessibility of *S. laticeps*. If it were possible to find a suitable pathogen and to infect the mites found on the aerial parts of plants, then migrating mites could potentially carry the infestation back down to the mites living within the bulb.

## PART 3 - DISCUSSION AND REFERENCES

### Discussion

*Steneotarsonemus laticeps* is a member of a genus which is entirely phytophagous, and whose members are restricted primarily or exclusively to monocotyledonous plants. *S. laticeps* itself appears to be confined to feeding on members of the Amaryllidaceae, and in particular to the genus *Narcissus*. The Amaryllidaceae are widely spread throughout the warm temperate and tropical regions and the genus *Narcissus* is found throughout Europe, West Asia and North Africa (Clapham, Tutin & Warburg, 1962). However, it would appear that *S. laticeps* is restricted to relatively few European countries and parts of North America and, is known only from plants under cultivation. It would be interesting to know whether these records reflect the real distribution or merely reflect the interests of the recorders. It may well be more widely distributed and occur on wild growing members of the Amaryllidaceae. It is not known why *S. laticeps* is restricted to the Amaryllidaceae when there would seem to be other potential hosts among the Liliaceae, nor is it known whether there are some circumstances in which members of the Liliaceae could become infested.

It has become a major pest in cultivated *Narcissus* because the conditions under which the bulbs are grown, in order to achieve maximum output of flowers and bulbs, favour the mites rapid multiplication with a corresponding increase in the level of damage incurred. An expanding horticultural trade has also succeeded in spreading the species to areas possibly outside its normal distribution range. In all probability it is no problem in its wild hosts, if they exist, as its life history will have been adapted to co-exist with them. It is, after all, possible to find cultivated bulbs which contain low levels of the mites, and which show no signs of infestation and bulbs grown without forcing do not usually display such a high level of infestation. It is mainly the process of forcing which would appear to promote the rapid destruction of the bulb by the mites.

Although Ewing (1929) synonomised *T. approximatus* Banks var. *narcissi* and *T. hydrocephalus* Vitzthum, with *T. laticeps* Halbert, it would appear that he still considered that Vitzthum's specimens of *hydrocephalus* differed in a number of respects from *laticeps* and var. *narcissi*. Beer (1954) in erecting the new genus *Steneotarsonemus* in which he placed *T. laticeps*, appears to have accepted this synonomy. He examined specimens from Ireland and America, but does not appear to have looked at Vitzthum's specimens. It would be of interest to examine these and compare them with Ewing's and Halbert's specimens in order to determine whether the differences in *hydrocephalus* noted by Ewing were indeed significant and whether it is indeed synonomous with *laticeps*.

Apart from the work carried out by Blattny (1933) and Hodson (1934) there has been no further attempt to study the biology or physical requirements of *S. laticeps* and, in fact, very little is known about this mite which is such an important horticultural pest. Blattny found that the mites were negatively phototropic but, as they amass in large numbers and reproduce on the foliage and flowers, this is presumably only while the bulb is dormant. He states that the mites were active between 10°C and 20°C and became motionless at 3.5°C. He gives no information on temperatures above 20°C and the type of activity that is found between 10°C and 20°C is not defined, i.e. is it reproductive or physical. He obtained only a 10% infestation rate in bulbs overwintered at 2° - 6°C and 40-75% RH in light as opposed to a 30% infestation rate at 8° - 12°C and 70 - 95% RH in darkness. It would have been intersting to observe the infestation rate for bulbs kept at 2° - 6°C and 70-95% RH in the dark. In all probability the infestation rate would have been depressed regardless of the light regime. Many mites become inactive at lower temperatures and cease to reproduce. It would appear likely that *S. laticeps* has a life history adapted to living in a host which undergoes a very cold dormant period and that temperature is the most important factor regulating its biology. As the mites live deep within the bulb the role played by light is questionable. It would also be interesting to know the extent to which external humidity effects that within the bulb. Although bulbs gradually lose water during storage, the humidity within the bulb must generally remain high. Further experiments would be necessary to answer the questions posed by Blattny's work and particularly studies on the effects of temperature, humidity and light regimes, both independently of each other and in combination. This would establish the importance of these factors in biology of *S. laticeps*.

Hodson's experiments which were carried out at temperatures fluctuating between 4.4°C and 18.3°C (presumably this was a night/day cycle as his laboratory was only heated during the day) gave a life cycle of approximately seven weeks. This would appear to be reasonable for the time of year (February to April) and temperatures at which the experiments were carried out. He also made some observations on the duration of the different stages in the life cycle although, as he points out, none of the stages was individually isolated and so the times were only approximate. He gives details on the longevity of only one of his original females, and does not elaborate on the number of mites involved in the trials. He was successful in maintaining only two of his eight original mite cultures and although he appears to have provided a suitable culturing technique, it was one which made observations on individual mites difficult, if not impossible.

As previously mentioned future useful areas of research would include investigations on the effects of temperature and humidity on the life cycle, the latter presumably being of more importance in that part of the life cycle which takes place on the aerial

parts of the plant. In particular information on the role of temperatures, in depressing reproduction at the lower end of the scale, and in determining reproductive potential at the higher end , would be of considerable interest when considering the development of physical means of control during storage and forcing. It follows that the establishment of the upper and lower lethal temperatures would also be of benefit. Fox-Wilson (1939) quotes a thermal death point of between 37.8°C and 48.9°C for *S. laticeps* but does not say how this information was obtained. It is to be supposed that he was refering to the temperatures used during hot water treatment of the bulbs. Tarsonemid mites are very soft bodied, and from observations on similar mites (Cunnington, 1984) the upper lethal temperature quoted seems surprisingly high. The lower lethal temperature is unknown and is likely to be considerably lower than the temperature at which development is arrested.

As Hodson (1934) pointed out the concealed nature of the mites' natural habitat makes observations under natural conditions extremely difficult. Studies on the biology and life history will need to be carried out in the laboratory, but again the problem is that the living bulb does not make an easy or consistent medium on which to culture mites for laboratory investigation. The two recorded attempts at culturing *S. laticeps* (Blattny, 1933; Hodson, 1934) used very different methods. Blattny's use of a decoction of Hyacinth bulbs might be worth further investigation, not least because attempts to infest Hyacinth bulbs with *S. laticeps* failed (Gurney, 1966).

In order to make accurate observations on developmental times and longevity, it is necessary, not only to find a method of culturing populations but also, to be able to isolate individuals at all stages in the life cycle. A consistent food medium needs to be developed, and has to take account of the fact that the mites use piercing mouthparts to feed. There may also be a need to take account of possible seasonal differences in nutritional requirements as, for example, when they are feeding on storage tissue as opposed to green foliage. The laboratory investigations would need to be related to the field situation and there is, therefore, a need to be able to monitor accurately the populations on forced and unforced bulbs through several seasons.

Hot water treatment administered at the correct time of year and at the recommended temperature of 44.4°C for a period of three hours would appear to be the most effective means of control of *S. laticeps* if it is carried out correctly. Hot water treatment of all *Narcissus* stock before planting is anyway recommended as a routine treatment for stem nematode control. Hodson (1934) observed that annual treatment by this method would undoubtedly maintain a high and adequate measure of control, and Doucette (1936) concurred with this observation and added that bulb producers who followed a general thermal programme for their stock had experienced little problem with the mite. However, as

damage to the bulbs may occur, it is not always possible to treat bulbs for forcing in this way. In this case bulbs for forcing may be treated at the lower temperature of 43.3°C and for the shorter time of one hour (Winfield, 1965). This will control the mites but without killing the entire population, and such bulbs would need retreatment on lifting at the end of the growing season.

If the infestation remains undiscovered until forcing has begun, some form of temporary chemical control is necessary, and at present only one compound, endosulfan, is approved for use in the UK against *S. laticeps*. In the trials described above endosulfan appears to give effective control for a limited period. Dependence on a single compound, which is used repeatedly, cannot be recommended as problems with resistance are likely to occur. There would be some advantage in investigating other contact acaricides, such as pirimiphos-methyl, which have approval in other storage situations. Some work has already been done with pirimiphos-methyl (Wilkin *et al*, 1976) but the results are difficult to interpret and the work needs to be repeated.

In the future some 'novel' compounds may become available for the control of these mites. Insect growth regulators, and in particular chitin inhibitors, have been tested and been shown to have potential in controlling stored product mites (B.B. Thind, pers. comm.) and plant mites. They have not been tested against Tarsonemids. However, all methods of chemical control are likely to achieve only temporary success as the mites inside the bulb are unlikely to come into contact with the pesticide. This problem could be overcome by the use of a systemic insecticide, however the work of Gurney (1972), showing that *Narcissus* bulbs are incapable of translocating systemic insecticides, would appear to rule out the use of such compounds for the control of *S. laticeps*.

Fumigation would appear to offer a viable alternative to chemical control, and one which could be used at any time during the storage period. The experimental treatments have been carried out using a variety of ct-products and temperatures. Higher doses are required at the lower temperatures and this agrees with the general rule of thumb that a 5°C rise in temperature can reduce the dosage required to kill some pests by as much as a half. Thus ct-products of around 250 seem to be effective at temperatures of 15°C and below, and ct-products of 100 or less at temperatures of 20°C and above. The EPPO recommendations (Anon., 1974) would fall within this range and the MAFF recommendations (Anon., 1984a) should certainly result in a complete kill. Two pieces of work (Murdoch, 1975; Powell, 1977) would appear to cast doubt on this overall conclusion. However, neither author gives any information on how the methyl bromide was dosed or measured. Murdoch does not give the temperature at which the fumigation was carried out and Powell carried out his fumigations at a single temperature. The differences between cultivars reported by Murdoch (1975) may be more an indicator of badly controlled

experimental conditions than of real differences in mortality on the different cultivars. Both Murdoch (1975) and Powell (1977) reported phytotoxic damage occurring at their highest doses. In Powell's work this is likely to have been caused by the presence of 2% chloropicrin in the methyl bromide formuation he used, as chloropicrin is known to have phytotoxic effects. There is no indication as to whether or not Murdoch's methyl bromide formulation contained chloropicrin, but it is likely that it did, as the fumigations were carried out for him by Powell (Murdoch, 1975). Other workers (Purnell & Hague, 1965; Thomas, 1965) have used higher or similar ct-products without phytotoxic damage occurring. The issues raised, in Murdoch and Powell's papers, in relation to phytotoxicity and acaricidal efficacy on different cultivars require further investigation under well controlled conditions and with modern cultivars. Trials under properly controlled conditions may also help to tighten-up current dosage recommendations, with the possibility of reducing some recommended doses.

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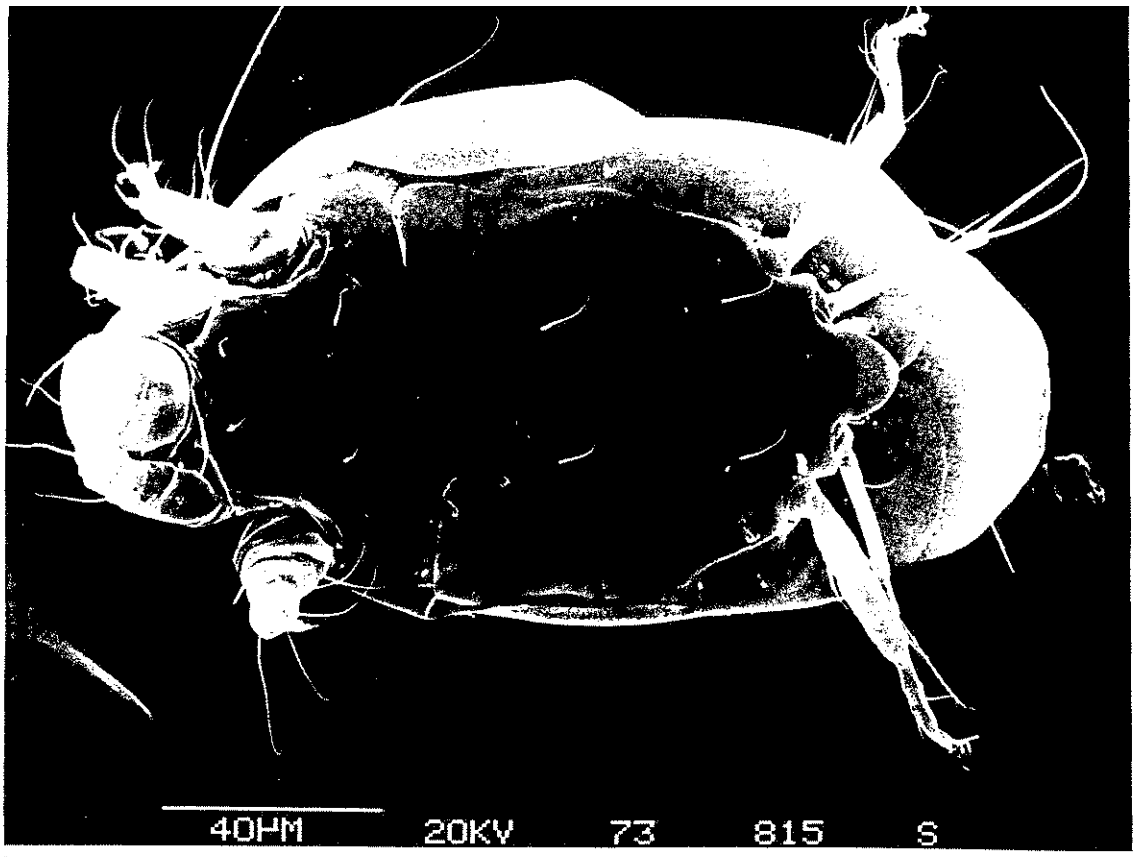


Plate 1. Female Tarsonemid Ventral View x 703

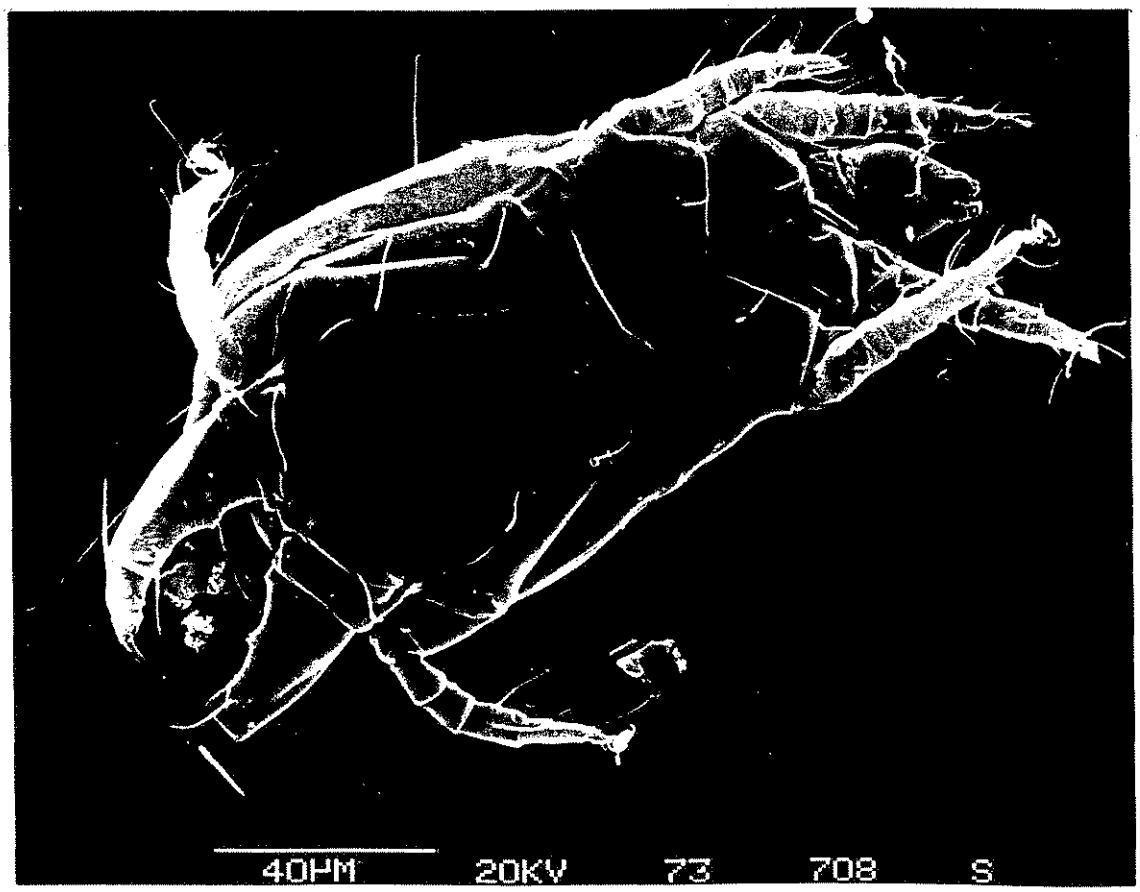


Plate 2 Male Tarsonemid Ventral View x 702

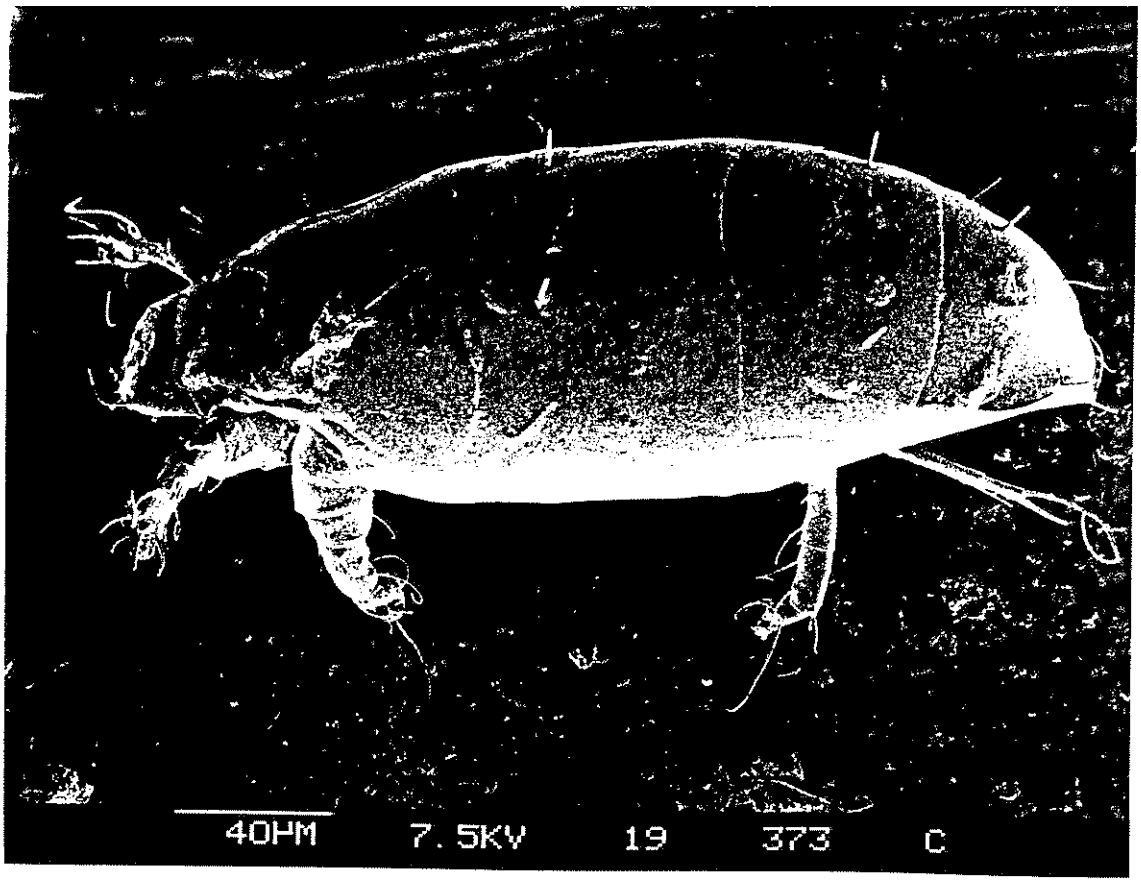


Plate 3 *Steneotarsonemus laticeps* female lateral view x500

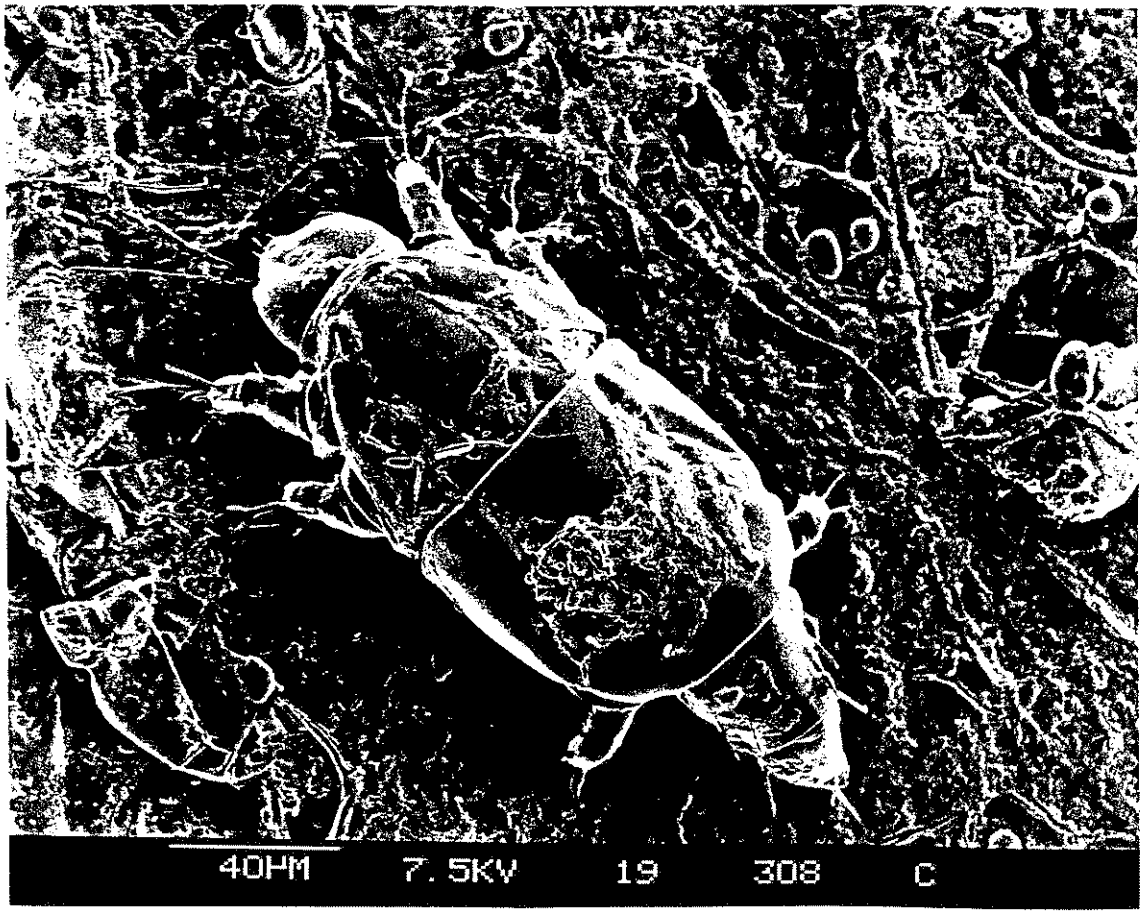


Plate 4 *Steneotarsonemus laticeps* larva dorsal view x 550

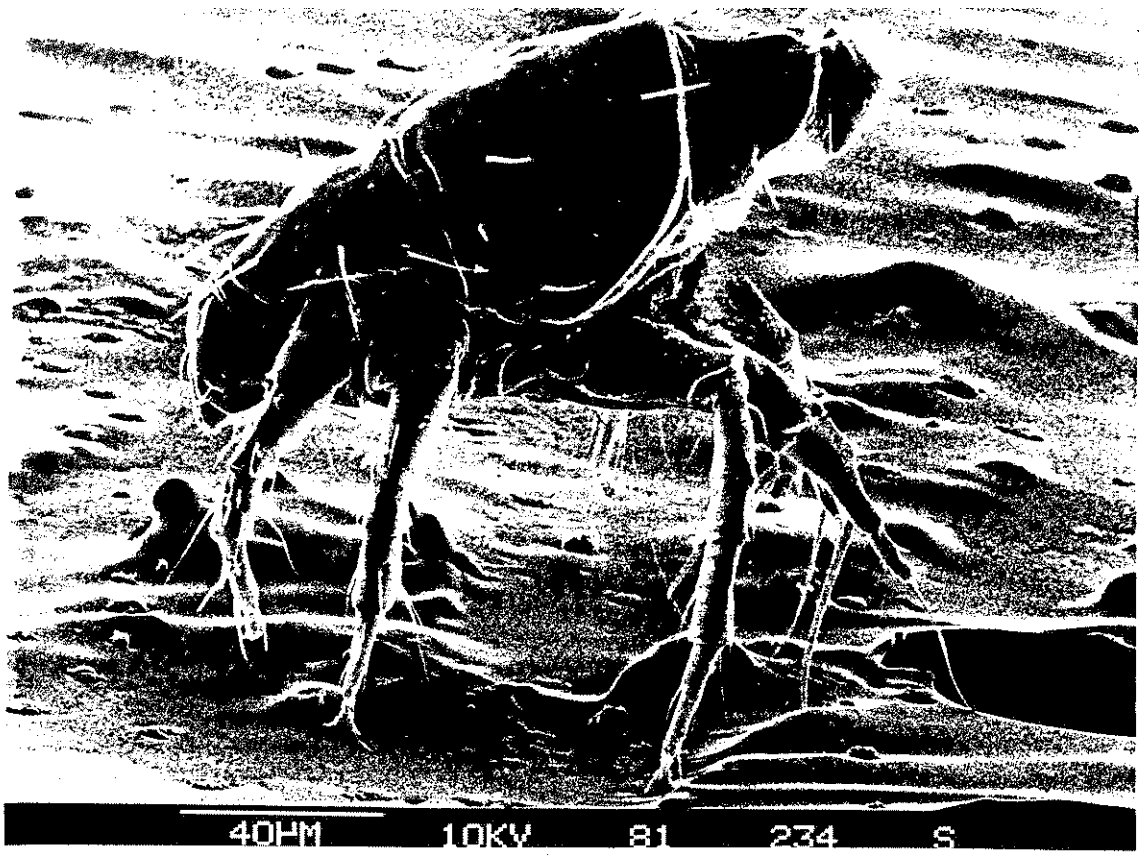


Plate 5 Male Tarsonemid x 650

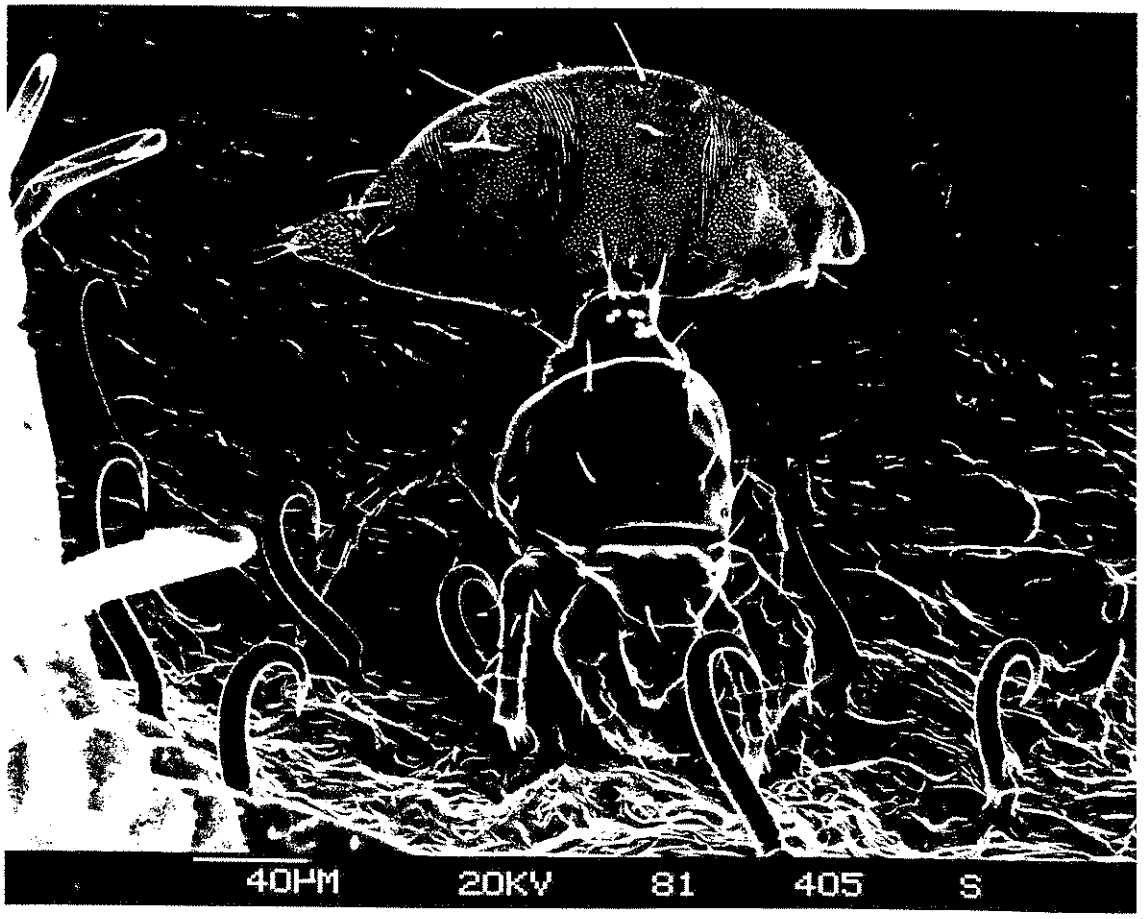


Plate 6 Male tarsonemid carrying female "pupa" x 363

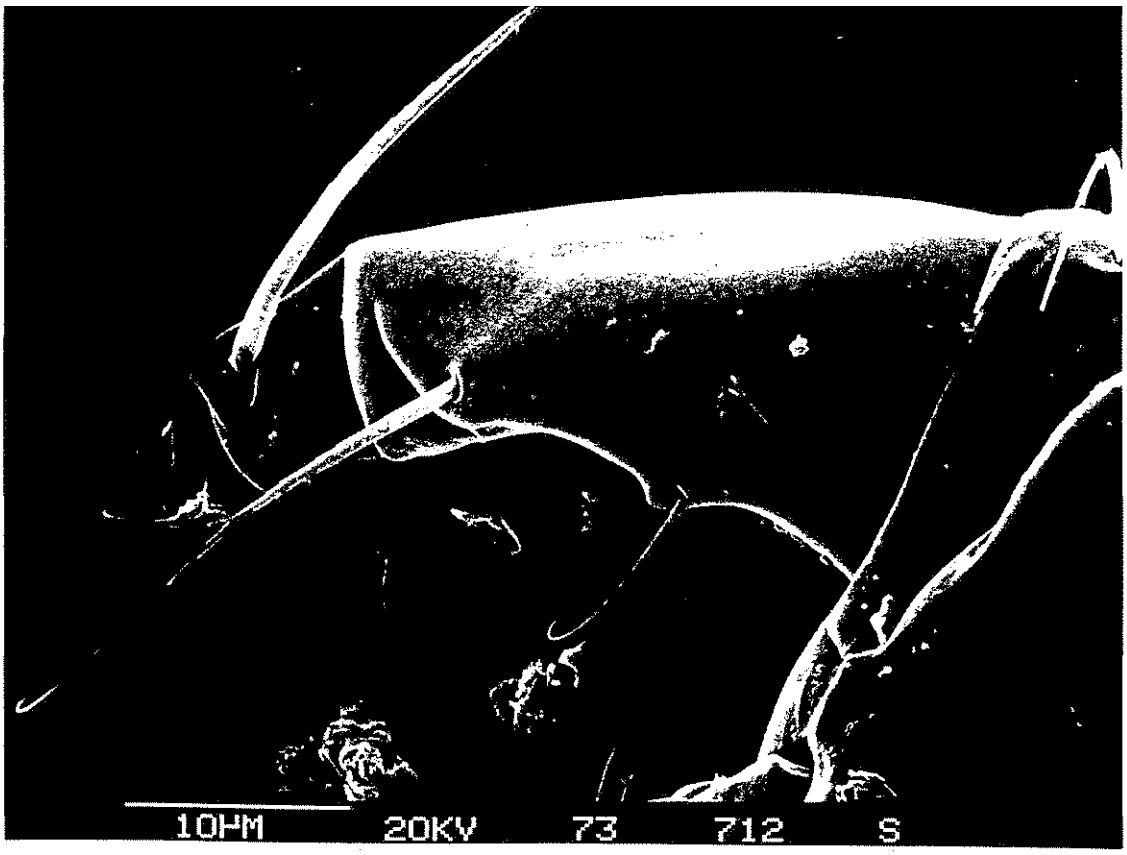


Plate 7 Male Tarsonemid Leg IV x 2,900

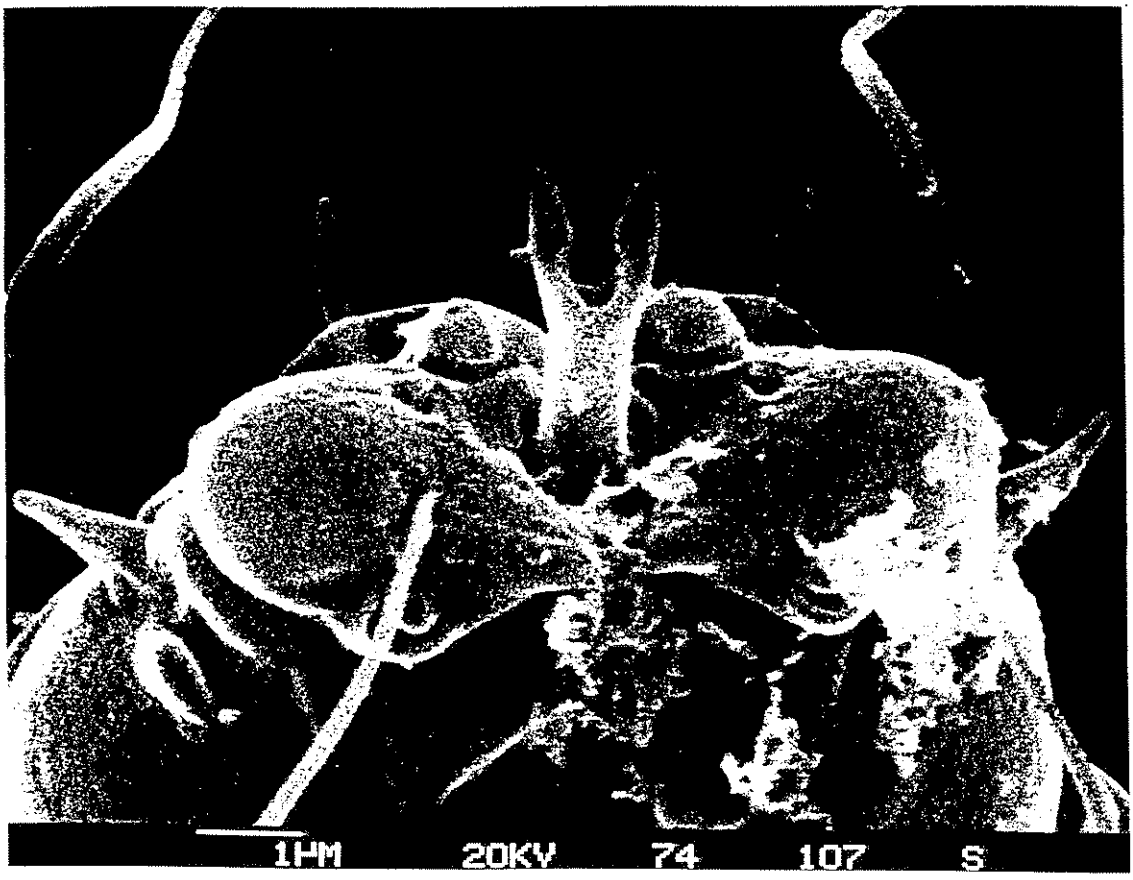


Plate 8 Tarsonemid Mouthparts x 13,000

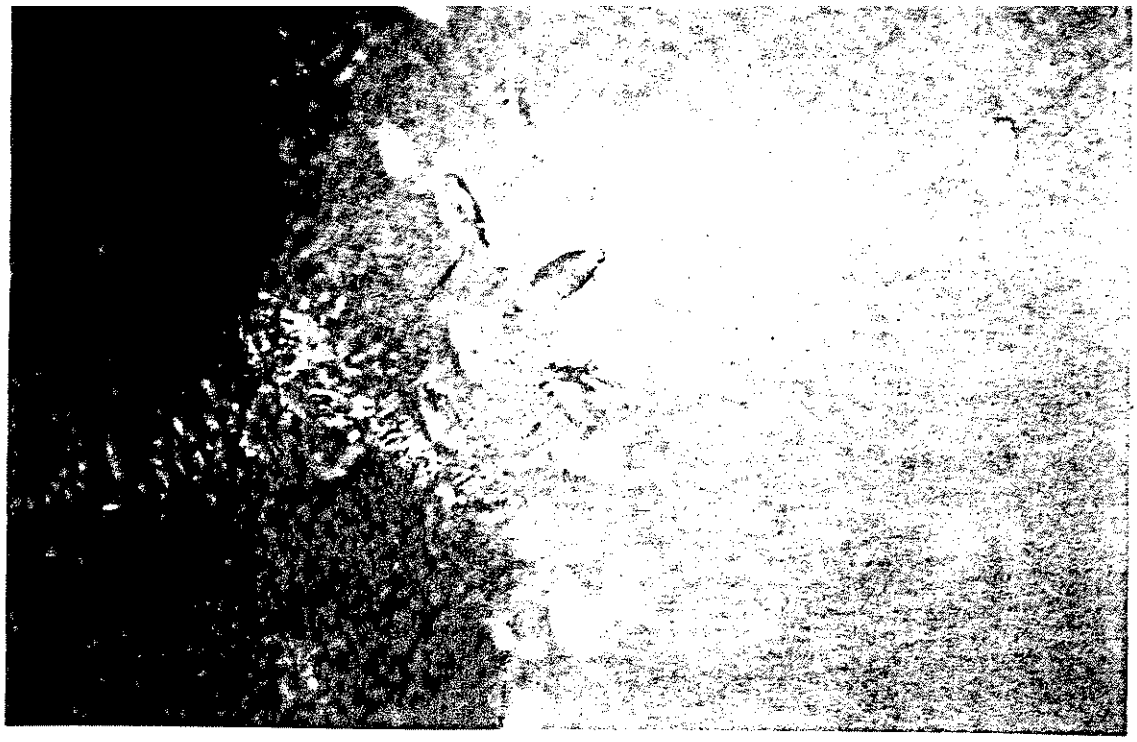

Plate 9 *S. laticeps* feeding on bulb scale x 40

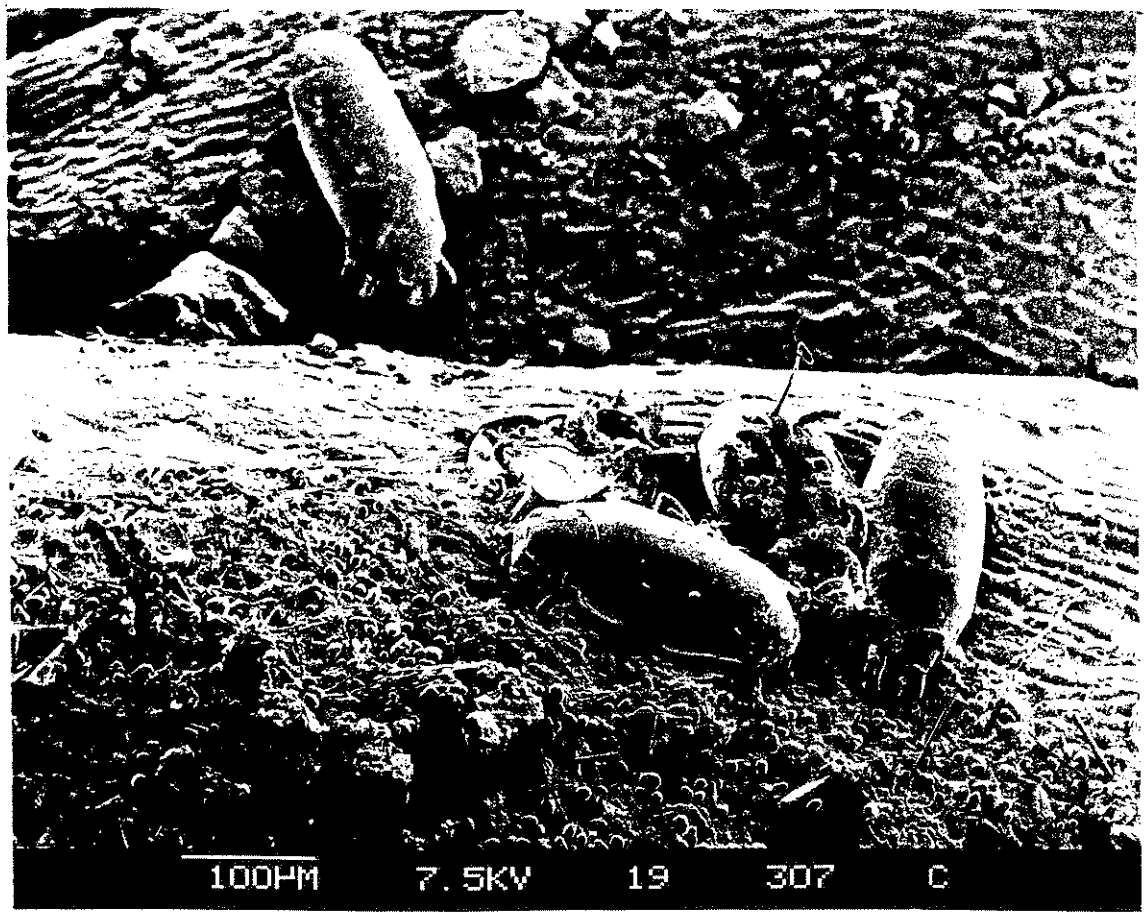


Plate 10 *S. laticeps* feeding on bulb scale x 170