THE ROLE OF CAPSID BUGS IN FRUIT MALFORMATION OF STRAWBERRIES

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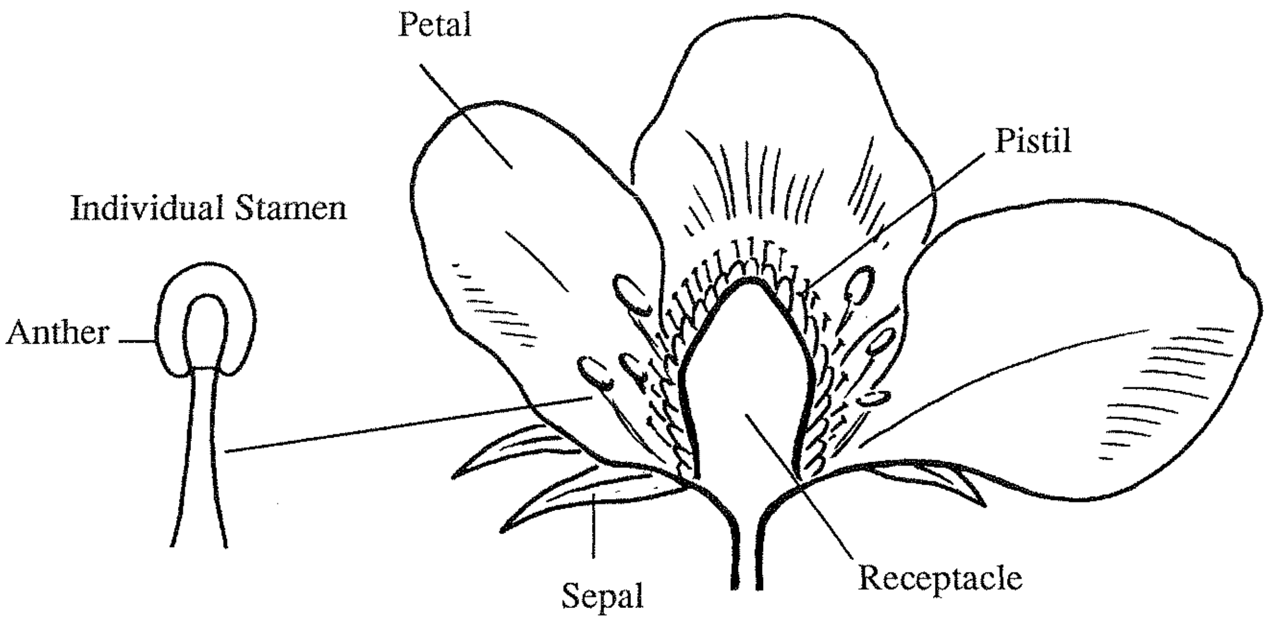
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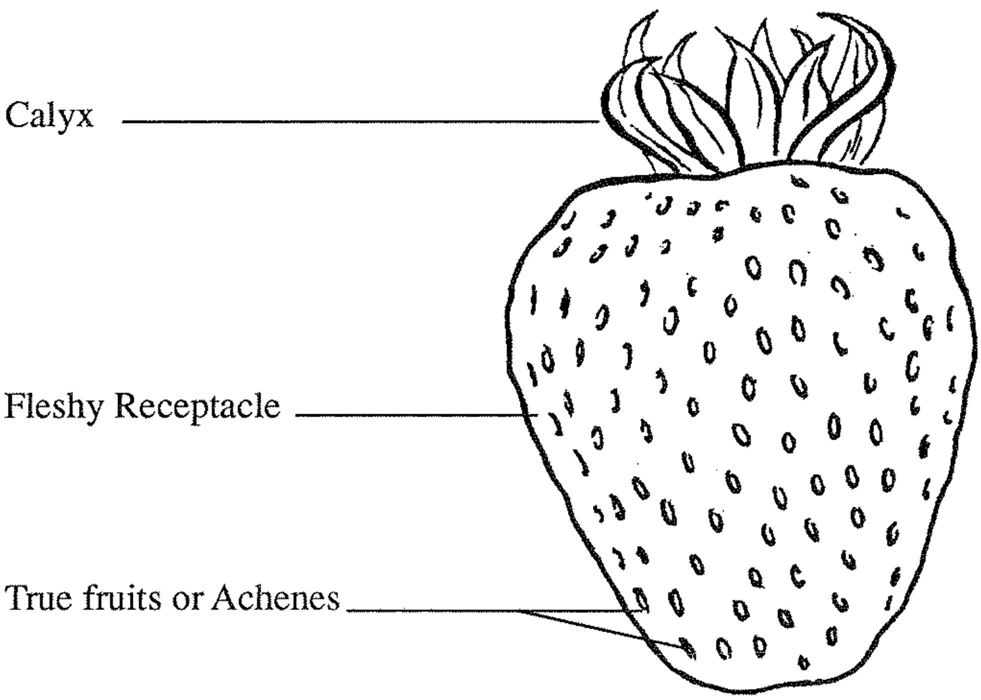
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The Role of Capsid Bugs in Strawberry Fruit Malformation

ABSTRACT

Malformation of strawberry fruits can be due to several causes, including poor pollination, frost, or pesticide application. However, the damage to late-season strawberries in the U.K. is probably due mainly to feeding by insects on flowers and young fruit. Research in North America has shown that capsid bugs can cause deformation of fruits, sometimes on a large proportion of the crop. The species that are most important there, *Lygus hesperus* and *Lygus lineolaris*, do not occur in the U.K. There has been little research on capsids on strawberries in Europe, but studies in Norway in the 1970s showed that various species could cause fruit malformation there. Observations in the U.K. have shown that insecticide treatments can reduce fruit malformation on late-season strawberries, and that a species of capsid called *Lygus rugulipennis* may be the most important agent of damage though other species of capsids may be involved, and possibly thrips also. Any insect feeding damage will result in malformation of fruit in harvests 3-4 weeks later. Practical information to help growers combat the problem is given.

The Role of Capsid Bugs in Strawberry Fruit Malformation

Introduction

Since the early 1980s strawberry growers in the U.K. have reported losses due to malformed fruit on everbearer (day-neutral) varieties. Losses have been severe in some cases in recent years, and have also occurred on '60-day' plants of cv. Elsanta. The causes of malformation, which may be diverse, have not always been clear. The possibility that the European Tarnished Plant Bug, *Lygus rugulipennis,* and related capsid species were the cause of the problem was suggested by Cross (1992). Since then growers have recognised a link between fruit malformation and the presence of capsids. The purpose of this review is to collate existing information about strawberry fruit malformation and the potential role of capsids on a worldwide basis, with a view to providing practical information to growers and to identify areas for future research in the U.K.

Development of the strawberry fruit

To help to understand how malformation can occur it is necessary to have some background information on the structure and physiology of the strawberry fruit. The strawberry is an aggregate fruit consisting of an enlarged edible receptacle that bears small seed-like achenes on its surface which form the true fruit. Individual achenes result from the fertilization of a pistillate flower located on the receptacle. It is this receptacle tissue which makes up the edible fruit. Successful pollination and fertilization is required for each achene to continue growth and during this development the achene releases plant hormones into the surrounding receptacle tissue which results in the growth of that tissue. Deformed fruit can therefore arise from:

a) unequal distribution of achenes,

b) areas of unfertilized achenes, or

c) interference with hormonal release following fertilization (Howitt *et al.,* 1965; Nitsch, 1950; Parker *et al.,* 1978; Schaefers, 1963).

Possible causes of malformed fruit other than insect damage

Inadequate pollination, leading to lack of fertilization, can lead to fruit deformity. Poor pollination can arise from a lack of pollinating insects, low pollen viability or poor pollen tube growth, and these can be affected by climate and other factors (Schaefers, 1963). Environmental factors such as short days, low light and temperature extremes during anther development can affect anther quality and pollen viability. Also, pollen germination can be affected by deficiencies of calcium, boron, manganese and zinc (Riggs, 1990). Injury to pistils, anthers or pollen can be caused by high temperatures, hot drying winds or cool wet periods. Injury can occur anywhere on the fruit, but it usually shows as furrowed or sunken areas running from the shoulder downwards. This causes a gnarled or twisted strawberry. Very often the malformation occurs as a deep ridge partially closed by the development of the receptacle (Howitt *et al.,* 1965).

Other studies have shown that frost (Modlibowska, 1968) or pesticide applications (Bennett, 1969; Takahashi, 1973) can result in fruit deformities.

Role of capsid bugs in fruit malformation

Capsid bugs are in the Insect Order Hemiptera, Sub-Order Heteroptera. Insects in this sub-order have long, needle-like mouthparts which they use to pierce plant tissue and suck out cell contents. They may also inject enzymes in the saliva that affect plant growth. Some heteropterans are predatory, e.g. Black-kneed Capsid, anthocorids.

Capsid bugs are known as pests of a wide variety of agricultural and horticultural crops in most parts of the world. Below we report the importance of capsids on strawberries in the major growing areas of northern temperate regions and record which species are important in particular areas. North America and Europe are dealt with separately, because although it is clear that capsids are important in both areas, and that there are clear parallels between the regions, the species of capsids involved are different.

(a) United Kingdom

There is very little information in the literature on capsids on strawberry in the U.K., though the common green capsid, *Lygocoris pabulinus* is a well-known but infrequent pest, causing distinctive damage to foliage and flowers, which may result in gnarled fruit. Massee (1956) states that *Lygus rugulipennis* frequently occurs on cultivated fruits and hop but is not regarded as harmful. The standard works of Massee (1954) and Alford (1984) make no reference to fruit malformation. Alford mentions only one capsid on strawberry, the common green capsid *Lygocoris pabulinus*, and states that damage is limited to the leaves. Of course, late season strawberries are a fairly recent introduction to the U.K. and it is likely that numbers of capsids increase too late to inflict much damage on June-bearers. The species implicated in causing malformation in Norway, i.e. *Plagiognathus arbustorum, Lygus rugulipennis* and *Calocoris norvegicus* all occur in Britain, and are stated to be common and widespread on a range of plants in various habitats (Southwood & Leston, 1959). *Lygus lineolaris* and *L. hesperus,* the species cited as causing fruit malformation in the USA, do not occur in the U.K.

In 1991 a crop of Selva strawberries near Maidstone, Kent was visited by J. Cross of ADAS (Cross, 1992). The grower had reported severe and persistent malformation of fruits and could not identify the cause. Large numbers (1-2 per plant) of capsid nymphs and adults were present in the crop. The bugs in a small sample were identified as *Lygus rugulipennis* by a specialist. The insects were clearly feeding in the flowers, so were likely to be the cause of the problem.

In the winter of 1992-3 growers and advisors who had been alerted to the potential problem at the beginning of the 1992 season were contacted to gauge their experiences. The consensus was that a large proportion of everbearer and 60-day crops, probably exceeding 50% of the crops, were infested with capsids in 1992. Several growers suffered severe losses due to malformed fruit which they linked, probably without clear evidence, to the capsid infestation. The problem was most noticeable where broad-spectrum pesticides had not been used in order to conserve *Phytoseiulus* predators.

Many growers were not aware of the problem until an unexpectedly large proportion of malformed fruit was picked.

In trials on everbearer strawberries in the U.K. where repeated applications of insecticides were made (Buxton & Easterbrook, 1988; Easterbrook, unpublished) amounts of malformed fruit were reduced. In one trial damage was reduced from 16% of berries on untreated plots in early September to 2% on insecticide-treated plots, and from 41% to 3% in early October. In other trials damage in picks throughout September was consistently reduced from 10-15% on untreated plots to less than 2% on plots that had received a programme of insecticides. Obviously, use of insecticides would not reduce malformation due to poor pollination, so this reduction of such damage was due to control of an insect pest or pests. Although capsids were not seen in flower samples from these fields it is possible that they were present at low density and caused some, if not all, of the damage. Thrips were present in large numbers in flowers in these trials. In other parts of the world some authors consider these insects to cause malformation of strawberries (Bailey, 1938; Marshall, 1954; Goodwin, 1985), while others state that they cause discoloration rather than malformation (Allen & Gaede, 1963; Alofs, 1987). They certainly cause damage to the pistils of the flower, but in tests at East Malling, where thrips were caged on flowers on potted strawberries, no increase in malformation has been observed (Easterbrook, unpublished).

A little is known about the life history of *Lygus rugulipennis* in southern England due to limited observations at Harpenden, Hertfordshire, made by Southwood (1956), and this information is summarised at the end of this report. More detailed observations have been made in southern Finland (Varis, 1972) and Scotland (Stewart, 1969) but at these latitudes there was only one generation of adults in summer, compared to two in England, so the phenology of the species is different. There are no detailed observations of the life cycle with particular regard to strawberry. They may build up on other crop plants and weeds before moving to strawberries in flower.

If, as we suspect, *L. rugulipennis* is the most important species of capsid on late-season strawberries in the U.K., at least in terms of greatest numbers, then there is likely to be feeding damage from adults from late July through to September. In August nymphs will probably also be present. *Plagiognathus* species are also adult in the July to September period, and have been found in fields of everbearers at East Malling, though in smaller numbers than *L. rugulipennis* (Easterbrook, unpublished). Any feeding damage from these bugs will result in malformation appearing at harvests 3-4 weeks later.

(b) Europe

In Norway field surveys in the late 1960s showed a statistically significant relationship between numbers of capsids and amounts of fruit malformation. The predominant species of capsid in collections made between 4 June and 7 August was *Plagiognathus arbustorum,* though in one field in early July *Lygus* species were numerous and there was 95% malformation in that field. Other species found in smaller numbers were *Lygocoris pabulinus, Plagiognathus chrysanthemi* and *Calocoris norvegicus* (Taksdal & Sorum, 1971).

Taksdal & Sorum (1971) carried out experiments in which they caged bugs on flowers of strawberry, cv. Zephyr. As few as one *P. arbustorum* nymph per inflorescence gave over 60% of fruits malformed and reduced fresh weight, and 4 nymphs per inflorescence gave 94% malformation. In another cage experiment in the field, where 10 nymphs were allowed to feed on flowers and young fruits for 5 days, around 50% of fruit became malformed. The distortion symptoms were different when nymphs fed in the flowers compared to when they fed on young fruits (photos in Taksdal & Sorum, 1971). They also did cage experiments with *Lygus rugulipennis* and found that they caused severe distortion of the fruits. On the conventional strawberry varieties that they were studying they found that the larval development of *P. arbustorum* coincided with the period of flowering and early fruit development in June, so providing the potential for damage.

They state that both *P. arbustorum* and *L. rugulipennis* have a pronounced preference for feeding on flowers and fruit of strawberry, rather than on the leaves. Attacks therefore cause little or no leaf damage, and this may be the main reason why these species had hitherto been overlooked as strawberry pests, even though they are widely distributed in the palaearctic region. *Lygocoris pabulinus* causes more leaf damage. They usually found this species in only small numbers but an attack in one field resulted in a high level of malformation.

In field trials in Norway, mainly on cv. Senga Sengana where the most numerous capsid was usually *P. arbustorum,* Taksdal (1971) found that one spray just before flowering with an insecticide such as dimethoate, fenitrothion or malathion reduced malformation to less than 10%, compared to 72-96% on untreated plots. A spray two weeks before first flower was less effective.

No other reports of fruit distortion by capsids or other insect pests on strawberry in Europe have been located. However, *Lygus rugulipennis* is recorded as a pest of raspberry and also potatoes, lucerne and chrysanthemums (Southwood & Leston, 1959). This species also causes damage by feeding on the seeds of sunflowers, and on onion and bean seed crops, in countries in eastern Europe (Kocka, 1985; Korcz, 1987). It can also be numerous on sugar beet and wheat (Varis, 1972), and causes damage to seedlings of pine by damaging the shoot tips (Holopainen & Rikala, 1990).

(c) North America

In North America capsid bugs have been recognised as important pests on strawberry for some time and are considered by several authors to be a major cause of fruit malformation. Two species of *Lygus* are considered to be the major culprits: in north-eastern USA and Canada *Lygus lineolaris* (known as the tarnished plant bug) is the commonest cause, but in California and the Pacific North-West it is *Lygus hesperus.*

The first detailed study was by Allen & Gaede (1963) in California. They caged *Lygus hesperus* on strawberry plants and showed that both adults and nymphs could cause fruit malformation. The greatest numbers of malformed berries were produced when the bugs fed on the fruit immediately after petal fall. Damage was also great when the bugs fed on open flowers, but there was less effect when they fed on closed flower buds or on berries that had enlarged to the point where the achenes were just starting to separate. They considered that the bugs cause deformity by puncturing individual achenes. When sufficient achenes are destroyed in an area, receptacle growth is affected and the berry develops unevenly. In extreme cases all achenes may be damaged and there is no fruit development. There was no evidence that direct feeding on the receptacle would cause deformity. The plants seemed to be most susceptible to injury by *Lygus* bugs from the time the flowers opened until the achenes had completed enlarging (some 13-16 days).

Schaefers (1963, 1966) studied strawberry fruit malformation in New York State. He found that on an everbearing variety nearly 100% of berries picked in October were unsaleable for either fresh or processed fruit. Applications of various insecticides reduced the amount of damage by up to 76% and he considered that this was due mainly to reductions in populations of *Lygus lineolaris.* Dissection of strawberry achenes that had been attacked by the bug revealed them to be devoid of contents. When destroyed in this manner receptacle growth ceases as though the achene had been removed. The bug often confines its feeding to the achenes on the tip of the blossom, thus resulting in a 'buttoned' or 'nubbined' fruit.

Lygus lineolaris overwinters as an adult in wooded areas, leaf litter or beneath the strawberry mulch. They resume activity in spring and begin to lay eggs. In seasons with average temperatures new generation bugs do not become noticeable until mid-June, by which time in New York State most of the early fruit is well along in development and there is little injury. However, in seasons with extensive warming periods prior to blossom, bugs may reach sufficient numbers early in the season to cause severe injury to the early fruits. The most important damage is done to late season varieties as numbers of the bugs have built up by then.

In later studies (Schaefers, 1972, 1980) it was found that on a June bearer two applications of any of several insecticides in May and early June reduced damage at harvests in mid-late June to 12-25% deformed fruit, compared to 81% in untreated plots. Similarly, on an everbearer variety two sprays in July reduced damage in August picks to 13-25% compared to 68% in untreated. Malathion and dimethoate were among the most effective insecticides, but single applications were ineffective; two or three were required. He showed a significant correlation between numbers of *Lygus* and the amount of damage on berries harvested around 25 days later. Also, on untreated plots with large amounts of damaged fruit there was a reduction in the mean weight of the berries. The results suggested that populations of one *Lygus* nymph per flower cluster could result in 20-30% damaged berries 3-4 weeks later, and a tentative action threshold for spraying was set at 1 nymph/25 flower clusters.

Handley (1991) studied the effect of *Lygus lineolaris* feeding at different fruit stages by caging bugs on individual flowers or fruits. Blossom death occurred in all cases where exposure to *Lygus* feeding occurred pre-bloom, in most cases at anthesis, and in two-thirds of those at petal fall. Apical seediness, i.e. a concentration of seeds at the tip of the fruit, was observed only when feeding occurred at petal fall or achene separation. Other types of deformity were most common when feeding occurred at achene separation or pink receptacle stage. All these conclusions need to be treated with some caution, however, as the number of fruits observed was small. The length of time that the flowers or fruits were exposed to feeding by *Lygus* also affected the extent of the damage. Increasing exposure to feeding greatly increased the proportion of non-viable achenes. He concluded that feeding by the bugs interfered with the process of cell expansion in the strawberry cortex. Feeding at early blossom stage prevented the cell expansion from occurring, so there was no development of the receptacle. After cell expansion has begun, i.e. during petal fall and achene separation, feeding inhibits only some cells, while others develop normally, resulting in receptacle deformation, the exact expression of which depends on the number and location of affected cells. Apical seediness is a severe example of such damage, where only cells around the basal portion of the receptacle are fully expanded. Feeding by bugs at the pink receptacle stage causes little visible deformity because cell expansion is nearly complete.

Riggs (1990) carried out tests on caged flowers on potted plants to study the effects of pollination and *Lygus* feeding, in this case by *Lygus hesperus,* on fruit shape and weight. In these experiments the presence of bugs had a significant effect on fruit deformity, while lack of pollination did not, but both factors led to a reduction in fruit weight. The stage of achene development when the *Lygus* feeding occurred had a significant effect on the degree of deformity. When feeding occurred during the early stages of achene development (within 1-2 days of pollination) significant deformity occurred, whereas feeding on a 5-day-old receptacle did not cause significant deformity, though fruit weight was greatly affected. Observations indicated that *Lygus hesperus* fed directly on the developing achenes. *Lygus* bugs are not known to be a problem on June bearing strawberries in the Pacific North-west, probably because their numbers are too low at the critical period for feeding injury, but they need to be controlled on day-neutral crops.

Zalom *et al.* (1990) state that *Lygus hesperus* is the key pest on strawberry in the central coast area of California and feeding results in a reduction of berry size and weight. The most serious damage, however, is fruit deformation or 'catfacing', which resembles damage resulting from lack of pollination. *Lygus* may also feed on the receptacle of mature berries, but no damage results. *L. hesperus* overwinter as diapausing adults, primarily on weeds or other crops adjacent to first-year strawberry fields, though some may overwinter in strawberry fields if migration occurred after transplanting, and they do overwinter in multiple-year plantings. *L. hesperus* feed on many other crops and wild plants and research is in progress in California to increase knowledge of seasonal weed preferences to try to suggest ways of managing populations by weed control or companion planting. The first generation adult *L. hesperus* are present in June/July and the second generation frequently reaches densities sufficient to cause 80% damage if not controlled. However, none of the insecticides registered at that time was considered to be very effective.

In Canada *Lygus lineolaris* is the most important species, and affects the crop in both quality and quantity. It reaches its maximum population density in the second half of June, when the fruit is at the green stage. A two-year field study showed that cv. Redcoat had a carrying capacity of 0.9 *L. lineolaris* nymphs per blossom cluster i.e. no loss of berry weight occurs below this population level. With action thresholds of 0.26 and 0.15 nymphs per blossom cluster, about 3.6% and 2% respectively of the berries could be injured. Studies have shown that various weeds act as a reservoir for the bugs and damage was lower in fields with fewer weeds (Bostanian & Maillaux, 1990; Vincent *et al.,* 1990). It is also a pest on raspberry in Quebec, where various pyrethroids applied twice reduced damage to 7-8%, compared to around 20% on untreated (Rivard & Clement, 1980).

Conclusions

1. A large proportion of the malformation caused to fruits of everbearer and 60-day strawberries in the U.K. is almost certainly due to insect pests.
2. The most likely insect pests to cause this damage are capsid bugs, of which the most numerous species in the critical July to September period seems to be *Lygus rugulipennis,* the European Tarnished Plant Bug.

Recommendations for Future Research

1. Survey fields of 60-day and everbearer strawberries using various sampling techniques to determine the best monitoring techniques, identify the species present and follow their life cycle. This should improve spray timing.
2. Relate amounts of malformed fruit to capsid numbers by comparing sprayed with unsprayed field plots.
3. Set up cage tests on potted strawberries to discover which capsid species/ life stages cause fruit deformity and to relate deformities to flower/fruit stage at which feeding damage occurs.
4. Carry out field trials to test efficacy of some candidate insecticides and assess benefits in terms of reduced fruit damage. Advise growers of the likely effects of these insecticides on any predators used in mite-management programmes.

European Tarnished Plant Bug: A Summary of Information for Growers

The European Tarnished Plant Bug *(Lygus rugulipennis)* has recently been identified as one important cause of malformed fruits on everbearer and 60 day strawberry crops. Other related capsid species may also be involved. The problem occurred in many crops in 1992. Practical information to help growers is summarised below.

Crops at risk and alternative hosts

Potentially any strawberry crop could be attacked by this pest but crops in flower in mid- and late-summer (everbearers and 60-day plants), when this pest is most numerous and where broad-spectrum insecticides are not being used in order to conserve *Phytoseiulus* predators, are at most risk. Fat hen, mayweed, nettle, dock and clovers are alternative hosts and their presence in or around crops will increase the risk of infestation. Damage to raspberry has also been recorded and primocane varieties in particular may be at risk.

Recognition of the pest

The adult European Tarnished Plant Bug has a typical capsid body form. It is 5-6 mm in length and highly active, making short flights if disturbed. The upper surface is densely clothed with short, fine, semi-erect hairs and the general colour varies from yellowish-green to light brown. The Common Green Capsid is much greener. A number of capsids have a similar appearance and confirmation by an entomologist is necessary. Nymphs are green and are smaller versions of the adult, but with the wings only partially developed. Nymphs have a distinctive pair of black dots on the upperside of each of the front segments of the body.

Distribution and abundance

The European Tarnished Plant Bug is a common insect in the English countryside. It is sometimes locally very numerous in late summer when second generation adults emerge.

Crop monitoring

On warm, sunny days, the insect is present mainly in flowers and is readily visible. If disturbed by a cast shadow or possibly noise or vibration it may fly away, usually only a few feet. Adults and nymphs may also scuttle away and hide amongst plant foliage.

Growers should examine their crops regularly for this pest throughout the flowering period. Several rows should be walked including those at the outer margins of the field. With good eyesight it is possible to rapidly scan thousands of flowers by eye and detect the pest in very low numbers. A jar should be carried so insects can be collected for confirmation of identity.

Life history

The insect overwinters as an adult amongst leaf debris in hedge bottoms, but possibly also around mature strawberry plants. The adults emerge on warm, sunny days in March or April, usually in small numbers as winter mortality is high. Eggs are laid singly during May, being inserted in the surface of the flower buds and possibly stem bases of various plants. They hatch after a short time depending on temperature and the larvae feed in the flowers. They become adult at the end of July and lay eggs giving rise to a late summer generation. The insect can be very abundant at this time and populations of 1-2 individuals per plant have been seen in flowering strawberry crops. The second generation becomes adult in September and there is considerable pre-hibernation flight activity as the insects disperse to overwintering sites.

Crop damage

The insect feeds principally in strawberry flowers and little, if any, damage to foliage or stems seems to occur. The insect probes the surface of the receptacle, especially round the tip, sucking the juices. Damaged parts of the flower then fail to develop whereas adjacent undamaged areas swell normally. Resultant fruit are malformed, 'buttoned' or 'nubbined' with furrows or sunken areas. Similar malformation can occur from poor pollination or fertilisation or possibly frost or pesticide application. **There is a three to four week interval between feeding damage occurring and malformed fruits being picked by the grower and damage may easily go unnoticed until picking.** Where the pest is not controlled very severe damage may result, with a large proportion of fruits being malformed.

Control

Cultural measures to reduce the likelihood of infestation by this pest should be taken where possible. These include cleanliness from weeds and leaf debris. However, control will largely rely on application of an insecticide.

A wide range of insecticides is very effective against capsids but short persistence organophosphates are favoured since harmful effects to *Phytoseiulus* must be minimised.

A foliar spray of malathion is the best choice and has been found to be very effective by growers. It works best in warm conditions. Other organophosphates, such as chlorpyrifos (Dursban, Spannit) and dimethoate, are also likely to control capsids, but have longer harvest intervals and are likely to be more harmful to *Phytoseiulus*. Pyrethoids, whilst effective, should be avoided because they are very harmful to predators. Applications should be made at the first sign of the pest. Do not wait for crop damage to be seen in the form of malformed fruit. Constant vigilance is necessary as further immigration of bugs may occur following a spray, so that repeated applications of malathion at 2-3 week intervals may be required from July onwards.

Malathion is harmful to bees and special precautions to protect bees must be taken. Local beekeepers must be notified and sprays applied early morning or late evening to reduce risk. Malathion is also harmful to *Phytoseiulus* predators, but these appear to be partially resistant. Leaving a short interval (at least a few days) between spraying and predator introduction is ideal. If application is made after introduction all may not be lost. However, two-spotted spider mite and *Phytoseiulus* levels should be closely monitored subsequent to any application and the predator re-introduced if necessary. In order to minimise risk to predators the spray should be applied with a non-air-assisted boom sprayer to the upper surface of the plant.

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