Project title:	The identification of overwintering predatory mites in strawberry and cane fruit, and investigation of on-farm production.
Project number:	SF115
Project leader:	Robert Irving, ADAS UK Ltd
Report:	Final
Previous report:	N/A
Key staff:	Robert Irving, Soft fruit consultant Chris Creed, Soft fruit consultant Janet Allen, Soft fruit consultant Chris Nicholson, Soft fruit consultant Mike Lole, Entomologist John Buxton, Entomologist
Location of project:	Soft fruit farms in all areas of England.
Industry Representative:	
Date project commenced:	1st March 2010
Date project completed (or expected completion date):	31st January 2011

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Robert Irving
Fruit Consultant
ADAS

Signature..... Robert Irving..... Date .....2 February 2011.....

Report authorised by:

Dr Tim O'Neill
Horticultural Research Manager
ADAS

Signature ..... Dr Tim O'Neill..... Date ...2 February 2011……

CONTENTS

GROWER SUMMARY

Headline

- The predatory mites *Neoseiulus californicus* (strawberry) and *Amblyseius andersoni* (strawberry and raspberry) have been found on crops in the spring, implying that they can overwinter in the open in the UK, surviving exposure to very low temperatures, and may also be resilient to conventional pesticide regimes.

Background and expected deliverables

Strawberries and raspberries are commonly damaged by the two-spotted spider mite *Tetranychus urticae* (TSSM), especially summer-long everbearer strawberry and primocane raspberry crops. Acaricides are used for control, but dense crop canopies and restrictions on harvest intervals reduce their effectiveness, and there are concerns about resistance. Also, there is pressure from the multiple retailers to reduce pesticide residues, so that growers are becoming more interested in biological control programmes for TSSM.

The most popular predatory mite for TSSM control is *Phytoseiulus persimilis, which* is introduced during the summer months and can be very effective. However, this species only feeds on spider mites, has no cold tolerance and dies out when prey is scarce. Observations by ADAS consultants have indicated that predatory mites are present in early spring on some farms, at a time before *Phytoseiulus* mites have been introduced. The species involved have been unknown, but clearly could be of great importance in the overall control of spider mite.

The aim of this project therefore was to identify and quantify the predatory mites that occurred naturally on strawberry and raspberry in spring, having overwintered, and to determine the factors which might favour their existence.

Summary of the project and main conclusions

This project identified predatory mites in 51 out of a total of 55 samples collected from all the main fruit growing areas of England. The most common species overall, although found only on strawberry, was *Neoseiulus californicus*, which is regarded by Fera as a non-native species, with a licence for release only under protection. This mite was found in 49% of all samples. Clearly, *N. californicus* is capable of surviving UK winters, and has established

itself widely in outdoor strawberries and also crops grown in Spanish tunnels. *N. californicus* was not found in any of the raspberry crops sampled; instead, the most common species on this crop was *Amblyseius andersoni*, (27% of all samples) which is a native species endemic to northern Europe. Both of these species of predatory mite can feed on many different types of prey, including TSSM, other small prey such as springtails, and even pollen when live prey is scarce. The only other predatory mite species identified was *Typhlodromus pyri* (11% of all samples), which is also a polyphagous species, best known on tree fruit as the key predator of fruit tree red spider mite (*Panonychus ulmi*). The exact role of these predatory mite species in the soft fruit ecosystem is unknown, but this aspect deserves further investigation.

Records of insecticide use at each sampling site were obtained, and showed that the most common actives ingredient used (in order of frequency) were: chlorpyrifos (e.g. Dursban WG); bifenthrin (e.g. Talstar 80 Flo); clofentezine (Apollo 50 SC); tebufenpyrad (Masai); abamectin (Dynamec); thiacloprid (Calypso); pymetrozine (Chess); and pirimicarb (e.g. Aphox). Not all of these actives were used at each site, but they show that both *N. californicus* and *A. andersoni* must have some degree of tolerance to some or all of these pesticides.

Financial benefits

High infestation levels of two-spotted spider mite or tarsonemid mite can result in a premature end to harvest of the crop. Pesticides are rarely effective at this stage due to the difficulty in achieving adequate spray coverage and the time required during picking to meet necessary harvest intervals. Bio-control, starting at an early stage, greatly reduces the risk of this problem. The introduction of predators needs to be managed carefully as considerations of temperature and pesticide use influence their effectiveness. A high level of over-wintering predators would greatly assist establishment of a bio-control regime, if not replace traditional introduction timings altogether.

Typical preventive biocontrol costs for strawberries

Phytoseiulus persimilis, one introduction @ 30,000 per ha	£120
Amblyseius cucumeris, 1-3 introduction @ 200,000 per ha	£40-120

Typical preventive bio-control costs for raspberries

Phytoseiulus persimilis, one introduction @ 30,000 per ha	£120

Early cessation of harvest could affect revenue as follows:

- One tonne of strawberries is worth £3,000, a total yield of 25 t/ha
- One tonne of raspberries is worth £7,000, a total yield of 12 - 20 t/ha

Action points for growers

- Growers should be aware of the presence of these mites.

- Regulatory changes for *N. californicus* would be needed to permit its addition to an outdoor biological control programme, to supplement the routine use of *Phytoseiulus persimilis*.

- In this manner, a more robust programme would be possible, with *N. californicus* and *A. andersoni* adding to the overall control of TSSM in the crop.

SCIENCE SECTION

Introduction

The two-spotted spider mite (*Tetranychus urticae*) is an important pest of strawberry and raspberry and can cause reductions in yield if not controlled.

Problems with this pest are becoming more serious as these crops are grown more widely in Spanish tunnels and glasshouses (Easterbrook et al, 2001). Chemical control is difficult, due to the restricted number of approved pesticides, and resistance to many acaricides. Additionally, there are many pressures on growers to reduce pesticide use (Easterbrook et al, 2001). Biological control, using the commercially supplied predatory mite *Phytoseiulus persimilis,* is practised by some growers. Research work has shown that it can control *T. urticae* successfully (Easterbrook, 1992). However, this predator has to be re-introduced each year as it does not survive the UK winter, and it is susceptible to many of the pesticides used on soft fruit crops. Also, during the summer months, temperatures above 25°C reduce the activity of this predator while favouring an increase in numbers of two-spotted spider mite, leading to loss of control (Force, 1967).

Previous research had shown that other predatory mites, notably *N. californicus,* could be found in strawberry crops in S.E. England (Jolly, 2001). In laboratory experiments these had survived doses of pyrethroid insecticides at several times field rate (Jolly, 2000; Easterbrook and Fitzgerald, unpublished data). Moreover, published research has shown that it can be a valuable predator of TSSM, and remains effective even at temperatures above 25°C, at which *Phytoseiulus* is ineffective (Helle and Sabelis, 1985). *N. californicus* is available from several biocontrol suppliers under licence from Fera, but the licence only allows release on crops that are grown in fully-protected structures.

From the evidence of earlier work mentioned above, it appears that this species is more widespread. There has been little quantitative evidence of its presence in other fruit growing areas of England. The aim of this project was to identify the species of predatory mite that had survived overwinter in unheated soft fruit crops, in all regions of England, and to try to relate their occurrence to crop type and pesticide use.

Materials and methods

ADAS consultants collected mite samples from second year or older overwintered crops of strawberry and cane fruit from a range of sites, giving a geographical spread across England. Each live sample was delivered within 48 hours to Mike Lole, specialist taxonomist within ADAS, for identification. Mites were transferred directly to a droplet of Heinz medium on a glass microscope slide, a cover slip was added and the slide warmed at 35°C for approximately one hour. The specimens were then examined using a Leitz Dialux phase-contrast, binocular light microscope and were identified with reference to taxonomic keys and descriptions of species.

A standardised survey form was designed for this project, which included details of the previous and current year's pesticide use, crop and environmental factors, and during the grower visits this data was collected and entered onto the form.

Crops of strawberry and primocane raspberry were sampled in the following counties (number of farms per county):

> Berkshire(2), Buckinghamshire(1), Cambridgeshire(1), Cheshire(2), Derbyshire(1), Devon(1), Essex(1), Hampshire(2), Herefordshire(1), Kent(1), Leicestershire(1), Middlesex(1), Norfolk(2), Nottinghamshire(1), Oxfordshire(2), Shropshire(1), Staffordshire(5), Surrey(3), Warwickshire(1), Worcestershire(2), and Yorkshire(1).

A total of 55 samples were collected, from 33 different farms. 38 samples were from strawberry and 14 samples from raspberry, with one sample each from blackberry, loganberry and blackcurrant. The majority of sites were unprotected through the winter, and only three of the sites were unheated permanent tunnels or glass. The period of sampling was between 25th March and 15th June 2010.

Results

The results of the survey are shown in Table 1 below

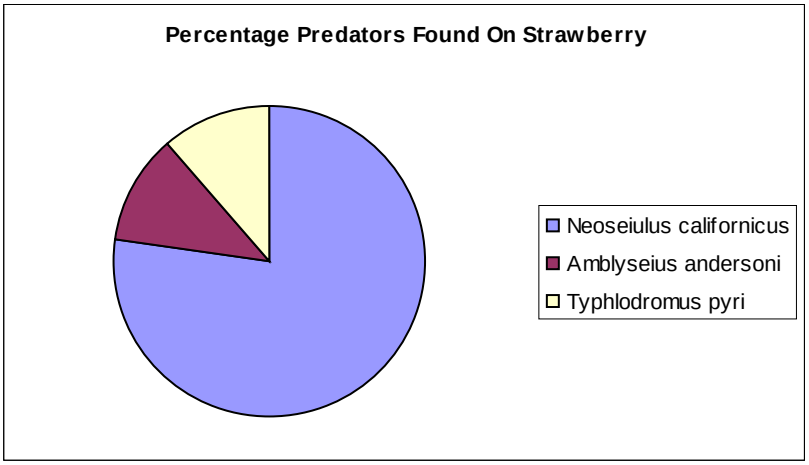
Table 1. The number of samples with predatory mites found during the sampling period in 2010.

	N. californicus	***A. andersoni***	***T. pyri***	***N. aurescens***	***Euseius finlandicus***	**None found or spoiled**
Strawberry	27	4	5	0	1	1
Raspberry	0	11	1	0	0	2
Blackberry	0	0	0	0	0	1
Loganberry	0	0	1	1	0	0
Blackcurrant	0	0	0	0	0	1

The results showed that only two species of predatory mite were common in the samples. These were *N. californicus* (49% of samples but only on strawberry) and *A. andersoni* (27% of samples, on strawberry and the dominant species on raspberry). *T. pyri* was found in 13% of the samples, but mainly from strawberry. The remaining species were very uncommon in this survey.

The results of the survey are shown as pie charts in Figures 1 and 2 below. Descriptions of the mites found are listed at Appendix 2.

Fig. 1 – Key predators found on strawberry

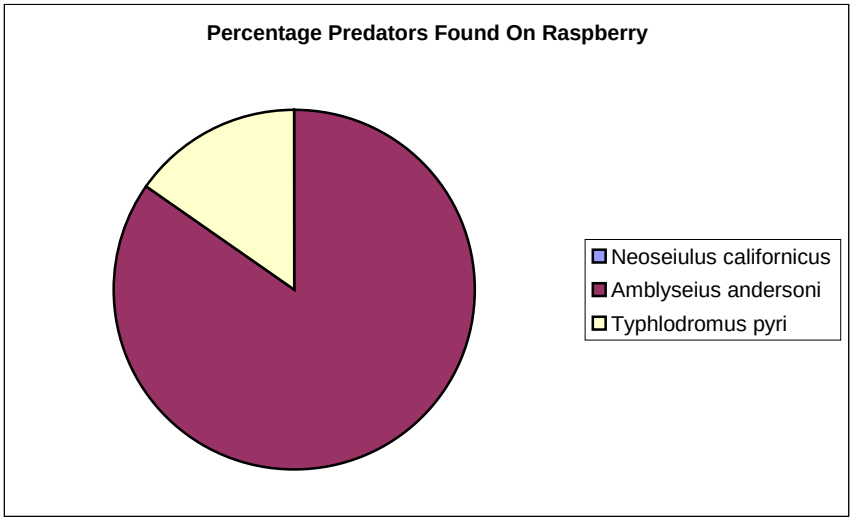


N. californicus presence on strawberry

This species was found on 27 strawberry crops on 19 farms. It was never found with other predatory mites or on the cane fruit crops sampled. It was found on sites (number of crops) in Cambridgeshire(1), Cheshire (1), Derbyshire(2), Devon(1), Hampshire(2), Herefordshire(1), Nottinghamshire(2), Oxfordshire(3), Shropshire(1), Staffordshire(10), Surrey(2) and Worcestershire(1), so is clearly widespread across all the fruit growing regions of England. How this species became established so widely is unknown. The Fera licence restricts release only to completely protected structures such as glasshouses but it is highly unlikely that growers were tempted to ignore the regulations and introduce it on outdoor or open-ended tunnelled crops as the species is very expensive.

22 crops had been planted in 2009 or earlier and so it was clear that the predator had survived the very cold winter of 2009-10. Five crops that were planted in early 2010 were in replanted beds, bags or troughs, suggesting a transfer of overwintering *N. californicus* from surrounding plants nearby. 20 samples were from raised bed and plastic systems, and five were from substrate-grown crops. A traditional soil-based system was used where two samples of this predator were found.

Fig. 2 – Key predators found on raspberry



A. andersoni presence on raspberry and strawberry

This predator was always found on its own, in four strawberry crops and 11 raspberry crops on 10 farms. At only a few farms had the grower introduced *A. andersoni* in the past and most in the survey had not. This mite species is native to the UK, and is recorded from a range of habitats including many trees and shrubs (Van der Linden and Nouwens, 2005).

It was found on sites in Berkshire, Essex, Herefordshire, Kent, Norfolk, Staffordshire and Surrey, so is also clearly of widespread distribution.

14 crops on which this mite was found had been planted in 2009 or earlier, suggesting that the species survived the cold winter of 2009/10. It was found on just one strawberry crop that had been planted in early 2010 and it was concluded that this mite emerged from the re-used bags in which the crop was planted. Nine samples were from raised plastic and soil beds, five were from substrate-grown crops and only one was from a traditional soil-based system.

Typhlodromus pyri presence in strawberry and raspberry

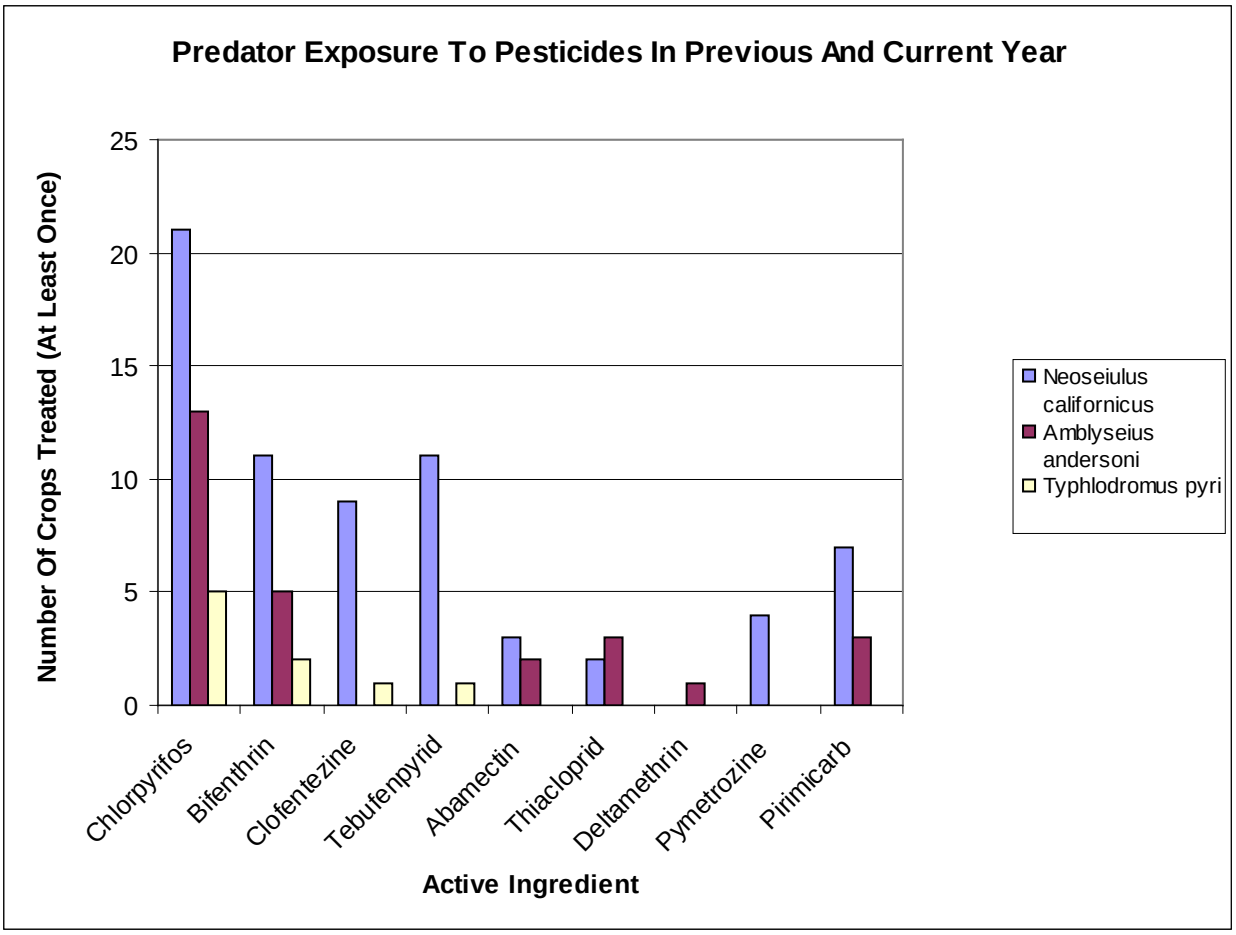
This predator was found in four strawberry crops, one raspberry crop and one loganberry crop over five farms. It was found on sites in Berkshire, Buckinghamshire, Cheshire, Devon and Leicestershire.

All six crops where this predator was found had been planted in 2009 or earlier and so this species had also survived the winter of 2009/10. All the crops where it was found used the traditional soil-based system of growing, usually in raised beds.

Use of pesticides in the sampling sites, and occurrence of predatory mites

This data is shown in bar chart form in Figure 3 below.

Fig. 3 Mite presence and insecticide use on strawberry and raspberry



The data in Fig 3 was gathered from growers' records during the farm visits. Exact correlations between use of an individual pesticide and occurrence of a predator are not possible from this data. The data does show that all three key predatory mite species appear to tolerate insecticide programmes commonly used. This is very helpful as it supports durable bio control populations within crops. The ability of *N. californicus* to develop tolerance to pyrethroids is well documented (Easterbrook et al, 2001) so it is not surprising that it was found where bifenthrin had been used. It was also found where

chlorpyrifos had been used, and so it is possible that tolerance to organophosphorous products is also present. There is little evidence in the literature regarding tolerance of *A. andersoni* to pesticides, but it is well known that *Typhlodromus pyri* has developed tolerance to some pesticides in top fruit orchards, both in the UK and worldwide (Watve and Lienk, 1976).

Future options for farm rearing key predatory mite species

Only *N. californicus* and *A. andersoni* will be considered in this section, as they were the most abundant species in the farm survey. There are several possibilities to augment the natural population of both species.

In the case of *N. californicus*, a change in the licence restrictions imposed by Fera would first be needed before specimens could be released outdoors. The evidence from this survey could be utilized in this regard. Assuming this is possible then augmentation could be provided by:

a) Banker plants spaced evenly amongst the crop.
The results from a previous HDC project (HNS 143) showed that both predatory mite species preyed on the lime mite, *Eotetranchyus tiliarum*, and that the lime mite was easy to rear on field grown small trees of the lime species *Tilia cordata.* Moreover, the lime mite only feeds on limes and cannot damage any other species of plant, so would be harmless to soft fruit crops. This technology could be taken up by committed growers, by placing containerized lime trees at intervals amongst the crop and infesting them, firstly with lime mites, and then predators, so that their numbers could build up and provide a reservoir of predators during the season. Migration from the banker plants onto the soft fruit crop would take place, aiding the biological control of TSSM.

It might also be possible to introduce the midge predator *Feltiella acarisuga,* and allow this to build up on the banker plants. This predator flies readily and can locate small colonies of TSSM, using chemical signals, so also aiding biological control.

b) Moving predator-infested foliage from older plants to newly planted runners.
Strawberry runners are frequently cut off, and leaves are removed for picker access at intervals. An assessment of the presence of predatory mites during leaf removal might allow collection of infested leaves in picker trolleys for transfer to maiden crops, thus “inoculating”

the new crop with predatory mites. At present, this material is left *in situ* on the crop paths, or swept up and discarded. Moving the *T. pyri* predator from one apple crop to another on summer prunings is a well established successful technique.

c) Inoculation of propagation material with predators, so that they become established on the new crop at an early stage. This happens rarely at present, but would be a simple measure to implement at the propagation stage. Because both *N. californicus* and *A. andersoni* can survive and increase even when TSSM is not present, by feeding on alternative prey, it is likely that establishment of both species would be more successful if the propagators inoculated runners at an early stage.

Discussion

This survey aimed to collect only overwintering mites, sampling was completed by mid June 2010. Commercially-reared predatory mites (e.g. *A. cucumeris* and *P. persimilis*) are not normally introduced until after this time, because numbers of TSSM are generally low in the crop until mid-late summer.

The three key predators, *N. californicus, A. andersoni, and T. pyri*, were nearly always found alone, i.e. in the absence of other species. Rarely were there other Phytoseiid mites present in the samples. The total number of mites in each sample was low, generally less than 10 mites per sample. If collections had been made later, in late June to July, greater numbers might have been found, but the results might have been confounded by the presence of predatory mites, including *Phytoseiulus persimilis*, introduced by the grower. A later survey might have shown a different balance of predators on the strawberry and raspberry crops. The interaction between the different species of predator is not known, but would repay further study in the future.

The overwintering survival of *A. andersoni* was not surprising, as it is a species endemic to northern Europe, but the widespread distribution and survival of *N. californicus* was not expected, and provides further evidence to work by Jolly 2000 and 2001 that the status of this species should be reviewed by Fera.

Conclusions

- *N. californicus* is widely distributed in English strawberry crops, and survives overwinter under commercial conditions.
- This species was not found in raspberry crops, but the reasons for this are not known at present.
- *A. andersoni* is common on both strawberry and raspberry crops, and also survives overwinter.
- The exact role of these predators in the biological control of TSSM during the season is not known, but would repay further study.

Knowledge and technology transfer

November 2010, Mike Lole, Presentation to HDC "Fruit Advisor Day"
March 2011, Robert Irving, HDC News article (Submitted)

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Appendices

Appendix 1: Farm Questionnaire

Adviser name and date collected	
Grower, farm name & county. Postcode would be nice.	
Crop, variety & planting date	
Describe where on the crop the predator was typically found, i.e. 1m up on raspberry canopy, ground trash, in crown of strawbs, near TSSM adults/eggs, etc. Also approx density of the mites found, e.g. lone individuals, several, clusters.	
Have bio control mites (phyto,	

Amblyseius species) ever been used on this crop? If so which, (especially for 2009), trade names will do	
Name any tough insecticides these mites would have been exposed to in 2009-10 e.g. chlorpyrifos, Masai, Talstar, Dynamec, Decis, Tracer, intensive sulphur programme for mildew. Collect 2009-10 records for this field if the farm can easily print out.	
Cropping system: We are primarily concerned with Spanish tunnelled sites that are removed for winter exposing the mites to 100% winter. Non-tunnelled crops could also be included. It's the proven winter survival that really matters. Describe the cropping system with this in mind.	

Appendix 2: More detail on the mite species identified in the project

i) Neoseiulus californicus

A non-native predator that is commercially available for introduction to permanently-enclosed crops, i.e. for glasshouse use only. It is not cleared for outdoor crop applications, as it is considered a non-native species in the UK. It is well documented in fruit crops of North America and southern Europe.

N. californicus is less than 1mm in length and pale brown. It is indistinguishable from other predatory Phytoseiid mites when using a hand lens. The key microscopic features that identify it are the form of the spermatheca and the shape of a pair of pores on the ventri-anal shield. It is polyphagous, and will eat two-spotted spider mite, tarsonemid mite, young

thrips, flower pollen, sugary deposits left by aphids, and fungi. It has a high level of pesticide tolerance and can survive British winters. It will continue to work at high temperatures (> 25°C) that inhibit the activity of another well-known predator of two-spotted spider mite, *Phytoseiulus persimilis*.

Mite for mite, *N. californicus* is not such an effective predator of two-spotted spider mite as the specialist *P. persimilis*, but its capacity to over-winter and build numbers makes this a very useful mite predator in fruit crops.

ii) Amblyseius andersoni

A native predator, like others it is less than 1mm in length and pale brown. The key microscopic features that identify it are the relative size of setae on the dorsal shield, the form of the spermatheca and the shape of the pores on the ventri-anal shield. It is polyphagous, able to eat two-spotted spider mite, tarsonemid mites, young thrips, flower pollen, sugary deposits left by aphids, and fungi. It is commonly seen in the absence of two-spotted spider mite. *A. andersoni* is commercially available from bio-control companies for release onto any crop.

Like *N. californicus*, A. andersoni is not such an effective predator of two-spotted spider mite as *P. persimilis*, but the capacity to over winter and build numbers makes this a very useful mite predator in fruit crops, perhaps particularly so in cane fruit where *N. californicus* does not seem to occur.

A. andersoni on raspberry

iii) Typhlodromus pyri

A native predatory mite, like the others less than 1 mm in length and pale brown; common in hedgerows and orchards. A valued, naturally-occurring predator of fruit-tree red spider mite (*Panonychus ulmi*) in top fruit crops. It is a predator of two-spotted spider mite, tarsonemid mite and young thrips. It is not readily available from bio-control companies.

iv) Euseius finlandicus & N. aurescens

Euseius finlandicus is recorded as a predator of Tetranychidae (spider mites) and Eriophyidae (rust mites, gall mites). *N. aurescens* is probably a mite predator.