Monitoring, identification and control of mites

The IPM approach

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Recognizing mites

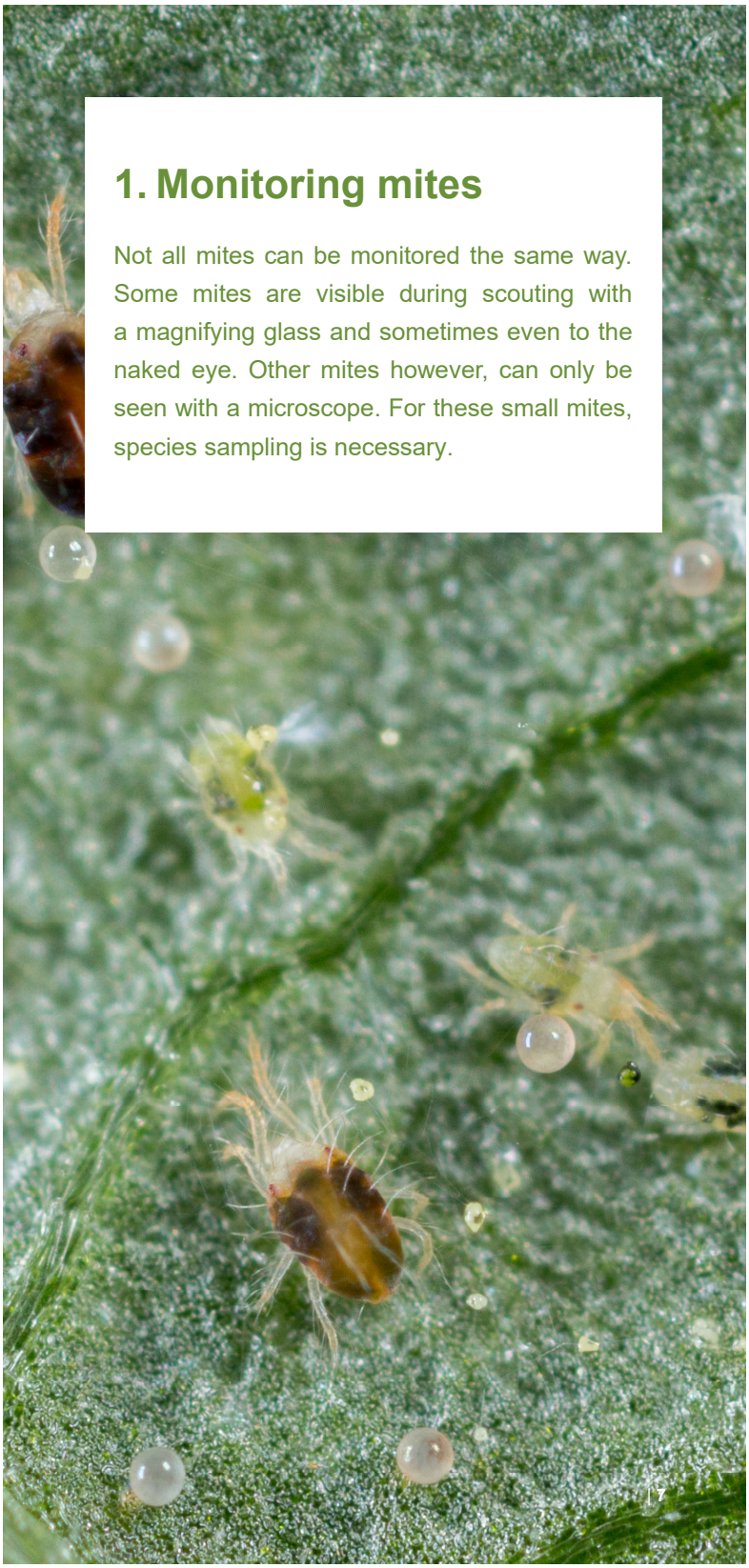
It is essential to know whether your crop is infested with pest mites and even more with which mite. Various species exist, all with their own typical features and symptoms. Besides mites that cause damage to plants, there are also beneficial mite species, which can be introduced as biocontrol agents. Other mite species are believed to be neither harmful nor beneficial. It is therefore important to know the difference between these types of mites, and distinguish the various species from each other. Only in this way efficient preventive and curative measures can be taken for optimal control.

Mites can be detected during scouting or sampling of the crop, and should be monitored on a regular basis. Besides knowing what the mites look like, it is also important to know what their damage symptoms are. In horticulture, mites can be found on leaves and flowers, whereas in fruit crops they are also situated on the fruits. The damage they cause differs depending on the plant structure.

In this guide you will get an overview of the techniques used for monitoring and sampling mites, the existing plant defence mechanisms, as well as keys for distinguishing the different mite species and the integration of beneficials to control them within an existing IPM system.

contents

This guide gives an overview of how to prevent, identify, monitor and control mite pests in woody ornamentals, soft fruit and citrus.



1. Monitoring mites

Not all mites can be monitored the same way. Some mites are visible during scouting with a magnifying glass and sometimes even to the naked eye. Other mites however, can only be seen with a microscope. For these small mites, species sampling is necessary.

1.1. SCOUTING THE CROP FOR MITES

Mites belong to the arachnids, which have 4 pairs of legs in their adult phase (exception are the eriophyoid mites which have only 2 pairs of legs in the adult phase). They are wingless and can therefore only be detected by scouting the crops. To be able to see the difference between different mite species (and other different pests) it is important to recognise them and their damage symptoms. Some mites are too small to be seen by the naked eye or even with a magnifying glass. At this point they can only sometimes be recognized by their damage symptoms and additional samples should be taken for further identification. It is not only important to recognise the pest, but also the beneficials which can control the pest.

When to scout?

It is recommended to scout the crops weekly in warm periods and every two weeks in cooler periods. If plant damage is detected, it is necessary to take a closer look using a magnifying glass, preferably with a magnitude of 15 times or greater, to identify the pest. Depending on the damage and whether the pest is visible or not, it will sometimes be necessary to take samples for microscopic analysis. It is good to inspect pest outbreaks, but it is even better to additionally inspect healthy plants (in the neighbourhood), because the sooner you discover a pest, the easier it is to control it.

About 3-5 days after a chemical treatment it is advisable to take another look to evaluate the control measure. The existing damage will not have changed (yet), but by using a magnifying glass, you can check if the pest is still alive. It is not necessary to keep treating the damage when the pest is already dead. Also evaluate the presence of beneficial mites, it is important to check your crop at regular intervals and check if the beneficials are near the pest.

How to scout?

Not every pest can be found at the same place on the plant. It is important to inspect every part of the plant. Most pests including mites are concentrated in the top of the plant, mostly on the underside of leaves or in flowers. They can also be found on the fruits. The diagram below shows where the different types of mites can be found on the plant (Figure 1).

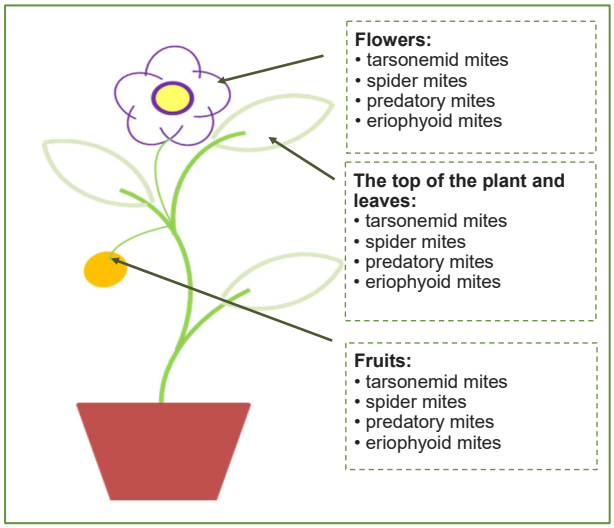


Figure 1: Position of the different mite types on the plant.

1.2. BERLESE FUNNEL

If during scouting it is not clear which pest you are dealing with, or when you want to know the number of (pest) mites, then (a part of) the plant can be further analysed with the Berlese funnel. This device consists of an upper part with a sieve in which the plant material is placed. Then a lamp is switched on to create heat. The mites in the plant material crawl away from the heat and tumble through the sieve, into a funnel and down into a cup filled with alcohol. After 24 hours all mites are collected in the alcohol. The alcohol preserves them nicely for later identification or counting under a microscope.

Figure 2: Detection methods. **Top:** Scouting with a magnifying glass. **Middle:** Berlese funnel. **Left bottom:** Microscope. **Right bottom:** Filtering system.

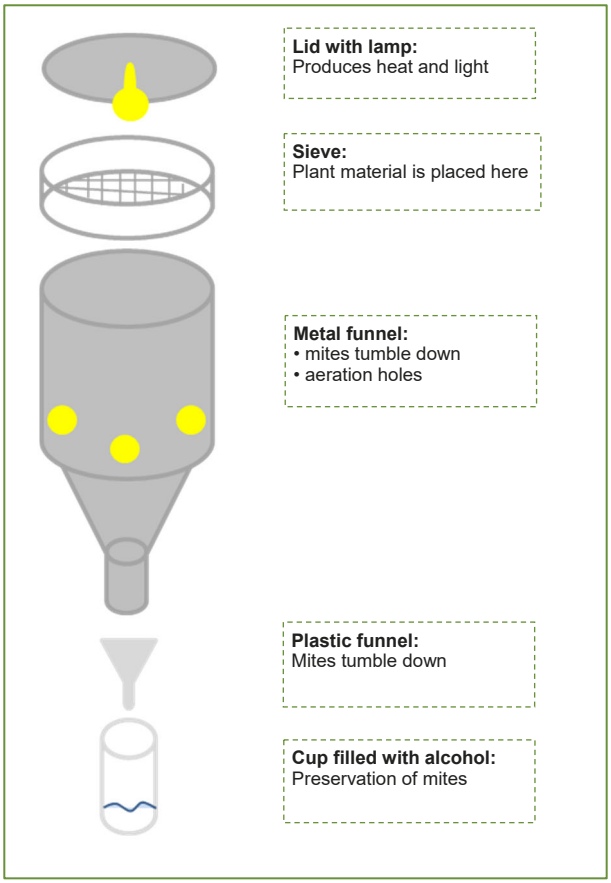


Figure 3: Berlese funnel.

1.3. SAMPLING WITH FILTRATION

Tarsonemid mites and eriophyoid mites are too small to be visible to the naked eye or with a magnifying glass, they can only be seen with a microscope. Because counting tarsonemid mites is not an easy task, PCS has developed an efficient sampling method. Plant samples are put directly into a closed cup of alcohol and shaken. After 24 hours all living tarsonemid mites have fallen into the alcohol and are collected in the cup. This liquid is then pushed through a filter, leaving the tarsonemid mites on the filter paper, where they can be counted

with a microscope. For further identification of the tarsenomid mite genera, a microscopic slide must be prepared. After drying of the slide, identification can be done with a microscope of 400x magnification. This is important to distinguish between the different species of tarsonemid mites, because not all species cause damage on plants. This method is also suitable for eriophyoid mites.

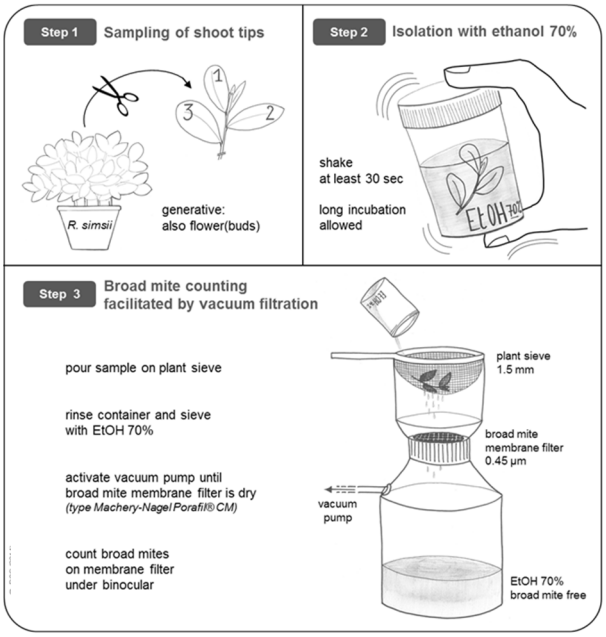


Figure 4: Detection method for small mites (and insects).
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1.4. STICKY TAPE METHOD

The sticky tape method may be used to identify the presence of eriophyoid mites in buds of overwintering canes of raspberry or blackberry. They are placed on a piece of sticky tape and left to dry at room temperature for 3 to 5 days. The idea is that eriophyoid mites emerging from the drying buds are caught on the sticky tape.

The mites on the adhesive tape are then observed and counted under a stereomicroscope at magnification 50-70x. The sticky tape method represents an interesting detection tool for growers, as it is fast, cheap and easy to perform. Distinguishing the different species of eriophyoid mites is not possible with this method however.

Figure 5: Sticky tape method. **Left top:** Sampling. **Right top:** Sticky tape with buds. **Bottom:** Eriophyoid mites on sticky tape as seen through a microscope

1.5. AZC METHOD

The Automated Zonal Centrifuge (AZC) was initially developed for the extraction of nematodes from soil, but it is also very useful for the extraction of eriophyoid mites. The separation is based on density and centrifugal force. A separation liquid (1.2 g/cm³) is used to separate the mites from water and plant particles. Mites are extracted from different parts of the plant (buds, leaves, twigs, etc.). Prior to extraction, plant tissues are blended to bring the mites into the water solution. The plant tissue is mixed in 0.5 l water for 15 seconds in a blender. The suspension is then transferred to a 1 l beaker and attached to the centrifuge. Every subsequent step (from sample supply to separation of the mites) is then performed automatically. At the end of the process, the mites are collected in a clear solution which can be examined under a dissection microscope.

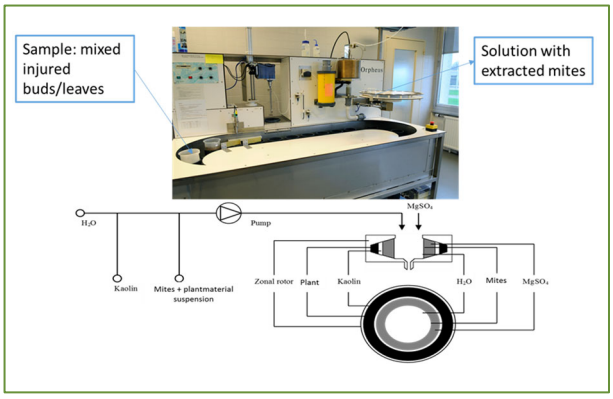
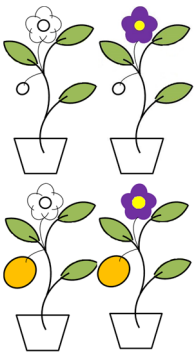
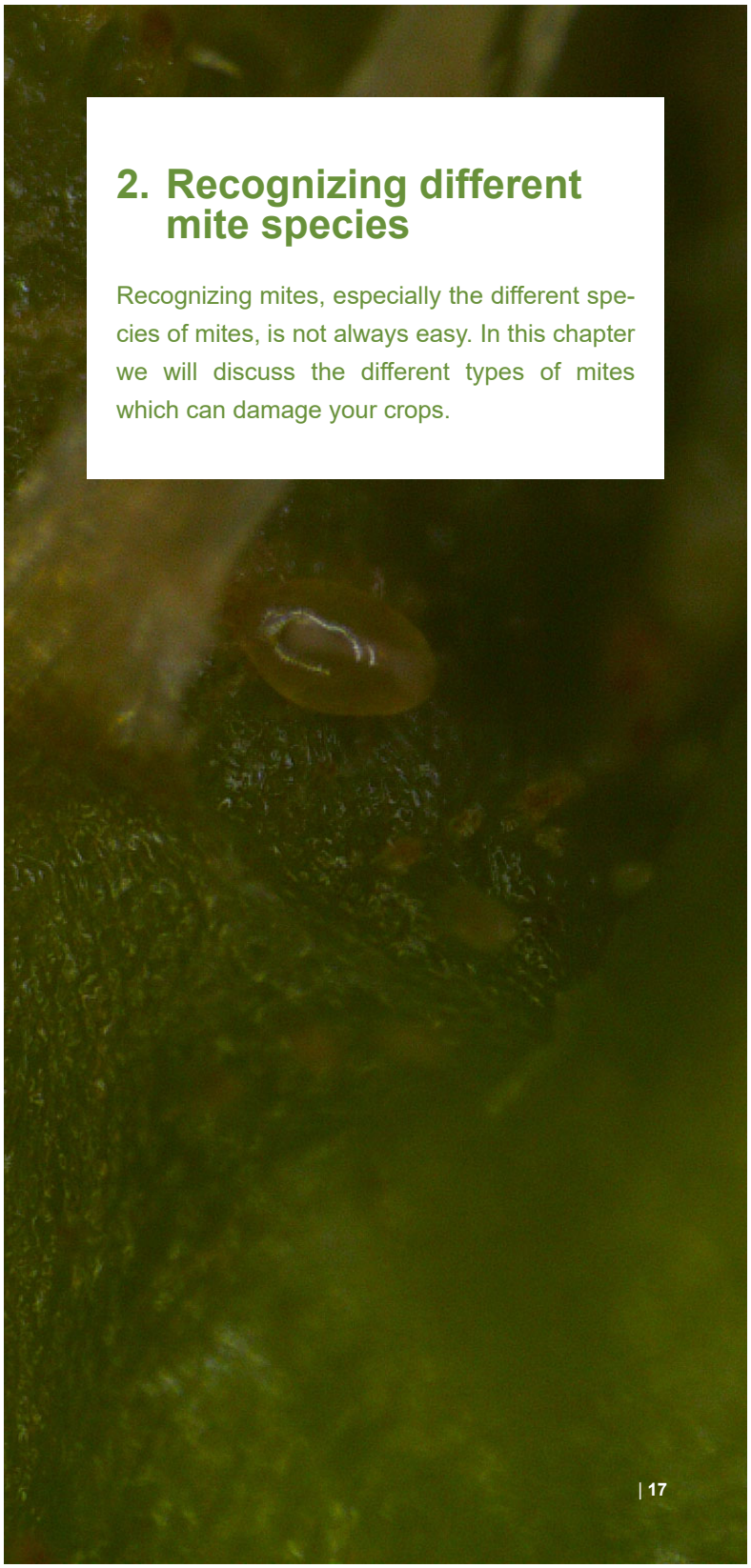


Figure 6: Automated Zonal Centrifuge (AZC).

SAMPLING METHOD	TYPE OF MITE	SAMPLE STORABLE	FAST METHOD	CHEAP	COUNTING MITES	IDENTIFICATION OF MITES	EQUIPMENT NEEDED
Mites live on sample	spider mites, beneficial mites	-	+	+	-	+/-	Magnifying glass/ microscope
Mites in alcohol	spider mites, broad mites, eriophyoid mites, beneficial mites	+	+	+	+	+/-	Microscope
Berlese funnel (mites in alcohol)	spider mites, beneficial mites, less for broad mites and eriophyoid mites	+	-	-	+	+	Berlese funnel + heat producing lamp, microscope
Sampling with filtration	spider mites, broad mites, eriophyoid mites, beneficial mites	+	+	-	+	+/-	Filter holder + black filter paper + vacuum pump, microscope
Wash and sieve (mites on filter paper)	spider mites, broad mites, eriophyoid mites, beneficial mites	+	+	-	+	+	Seeves + black filter paper, microscope
Zonal centrifuge (AZC)	eriophyoid mites	+	-	-	+	+	AZC + Kaolin and $MgSO_4$, microscope
Sticky tape method	eriophyoid mites	-	-	+	+/-	-	Sticky tape, microscope

LEGEND

max. 0,3 mm	Maximum size adult mite
	Best visible with magnifying glass
	Only visible with microscope
	Chemical control possible
	Biological control possible
	Situated on the plant: • Leaves • Leaves and flowers • Leaves and fruits • Leaves, flowers and fruits



2. Recognizing different mite species

Recognizing mites, especially the different species of mites, is not always easy. In this chapter we will discuss the different types of mites which can damage your crops.

2.1. SPIDER MITES
Tetranychidae

The life cycle of spider mites consists of five developmental stages: egg, larva, protonymph, deutonymph and adult. Development from egg to adult often takes one to two weeks, depending on the mite species, temperature, host plant, relative humidity and other environmental factors.

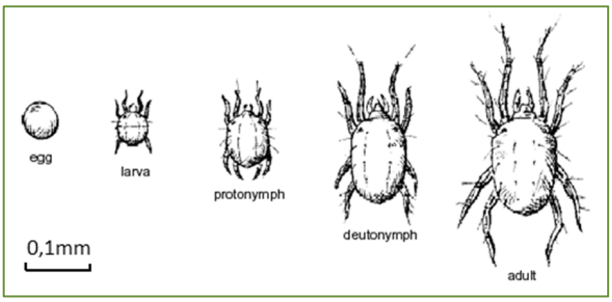


Figure 7: Life cycle of spider mites.

Spider mites are less than 1 millimetre in size and vary in colour. An average adult female is 0.4 mm in size, often red, green, orange or yellow. Males are almost half this size and paler than females, which makes them more challenging to observe. Use of a magnifying glass or a microscope at 15 times magnification is thus necessary. Spider mites are one of the most economically significant plant pests. Some of these mites cause serious damage to many food crops as well as ornamentals all over the world, both outdoors and in greenhouses. Due to their short life cycle, they are one of the organisms which are known for building up resistance against pesticides very fast.

TWO-SPOTTED SPIDER MITE

TETRANYCHUS URTICAE

These mites prefer the hot, dry weather of the summer and fall, but may occur anytime during the year. Many horticultural crops are sensitive to this mite, especially clementines, lemons, strawberries, tomatoes and different types of ornamental plants.

Webbing

Egg, nymph and adult spider mite

Red coloured adult

DAMAGE

- they live in colonies on the underside of leaves
- yellow dots on the upper side of leaves
- webs when severely infested: makes control difficult
- scars on fruit

MAIN HOST PLANTS

- broad host range, over 200 plant species

EGG

- convex, white-glazy = live egg
- pale-beige = dead egg

ADULT

- oval shaped
- colour: brown, orange-red, green, greenish-yellow or almost translucent
- two black spots on back
- two red eyes

max. 0.4 mm

CITRUS RED MITE
PANONYCHUS CITRI

Unlike other species, *P. citri* does not produce webs and shows a clear preference for leaves that have reached full development. The adult is found over the entire leaf surface, while the nymphs prefer the underside of the leaf.


Discolouration of fruit


Egg


Adult

DAMAGE
- diffuse discolouration of leaves and fruits
- silvering of foliage and fruit when severely infested

MAIN HOST PLANTS
- all citrus species (especially oranges), other fruits and ornamental trees

EGG
- convex, reddish, somewhat shiny
- fixed to substrate with thin threads of silk

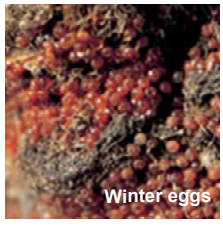
ADULT
- oval shaped
- colour: dark red or purplish
- with long hairs or setae inserted on pronounced tubercles

max. **0.5** mm

EUROPEAN RED MITE
PANONYCHUS ULMI

This mite causes damage by feeding on leaves. First pale spotting occurs, then as mite populations increase, the leaves turn 'bronzed', a characteristic appearance. The underside of the leaf turns brown and leaves may fall early when severely damaged.


Damage


Winter eggs


Winter egg and adult

DAMAGE
- pale spotting on leaves
- bronzed leaves
- early leaf fall

MAIN HOST PLANTS
- mostly fruit trees and ornamentals

EGG
- almost spherical
- 0.15 mm
- winter eggs: brick-red
- summer eggs: vary in colour

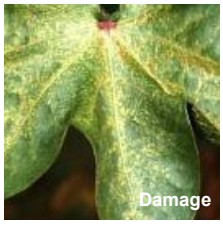
ADULT
- female: 0.4-0.7 mm, brownish-red body
- male: much smaller and lighter in colour
- pronounced tubercles

max. **0.7** mm

CITRUS BROWN MITE

EUTETRANYCHUS ORIENTALIS

Feeding begins on the upper side of the leaf along the midrib and then along lateral veins, causing chlorosis. Heavy infestation on citrus causes leaves to fall and die-back of branches, resulting in defoliation of trees.


Damage


Eggs


Male adult

DAMAGE

- chlorosis on the upper side of leaves
- pale yellow streaks along midrib and veins
- leaf fall
- defoliated trees
- little webbing

MAIN HOST PLANTS

- 2016 hosts, mostly Rutaceae and Fabaceae

EGG

- flattened disk, shiny

ADULT

- female: oval body, brown-green to dark-green, light coloured legs
- male: slender and triangular body shape, legs 3 times the length of body

max. 0.5 mm

2.2. TARSONEMID MITES
Tarsonemidae

Tarsonemidae have a reduced life cycle, with only two mobile stages: larvae and adults. The larvae have a brief feeding period and moult directly into adults.
Generation time may be one week or less and is dependent on host plant, temperature, relative humidity and other ecological factors. Unfertilized eggs become males and fertilized eggs become females.

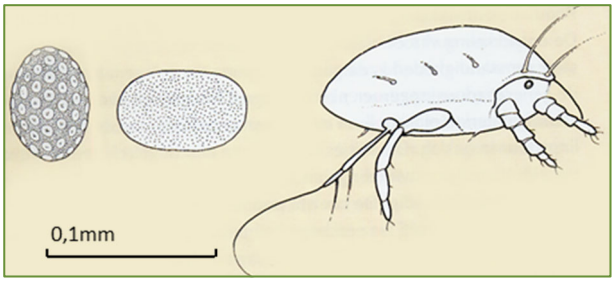


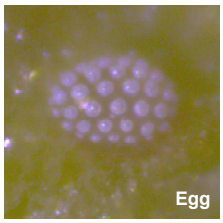
Figure 8: Life cycle of tarsonemid mites.

Tarsonemidae are very small mites (0.1-0.3 mm), which makes them impossible to observe to the naked eye or even with a magnifying glass. A microscope with at least 25 times magnification is thus needed. Their bodies are broad to elongated ovals with a hard and shiny cover. They are translucent, pale or white, but colour can be influenced by their food source, which can also result in green mites. The last pair of legs differs from the other legs; in females they end with a whip-like hair, whereas in males these legs usually terminate in a large claw.

BROAD MITE
POLYPHAGOTARSONEMUS LATUS

P. latus is often found on young leaves and mainly feeds on the underside of the leaves. It is a major pest throughout the tropics and in greenhouses of temperate countries.


Flower damage


Egg


Adult

DAMAGE
- sudden curling and wrinkling of leaves
- discoloration or blistering
- inhibited growth
- deformed flowers and flower stems
- plant death when severe

MAIN HOST PLANTS
- over 57 families including citrus, azalea, begonia, chrysanthemum, cyclamen, gerbera, hedera, hibiscus, impatiens, peppers, cucumber and more

EGG
- oval and bright, with white dots

ADULT
- oval shaped
- colour: amber to dark green, glossy
- with a white stripe on the back
- modified leg IV

max. 0.25 mm

CYCLAMEN MITE

PHYTONEMUS PALLIDUS

P. pallidus prefers young leaves or flower buds and feeds on the upper side of leaves. It is an important pest on many plant species.

Damage

Adult and egg

DAMAGE

- curled and twisted leaves
- plants distorted and reduced in size
- deformed flowers

MAIN HOST PLANTS

- azalea, begonia, chrysanthemum, cyclamen, geranium, gerbera, hedera, strawberries,…

EGG

- oval and pale, smooth

ADULT

- oval shaped
- colour: pale to yellowish brown

max. **0.2** mm

OTHER TARSONEMIDS

To be able to distinguish different tarsonemid species, a microscopic slide must be made. Together with the two previous tarsonemids, there are others which do not damage crops or which have not (yet) been proven to cause damage. In contrast, *Xenotarsonemus* spp. are believed to cause damage to plants, but as they never occur in large numbers on azalea, the damage is usually minor.

Here is an overview:

Tarsonemus confusus: no damage
Tarsonemus bilobatus: probably no damage
Tarsonemus floricolus: probably no damage
Tarsonemus lacustris: probably no damage
Xenotarsonemus sp.*:* probably damage

2.3. ERIOPHYOID MITES
Eriophyoidae

The life cycle of eriophyoid mites consists of 4 stages: egg, larva, nymph and adult. Immature stadia usually look similar to adults, but are smaller and lack external genitalia.

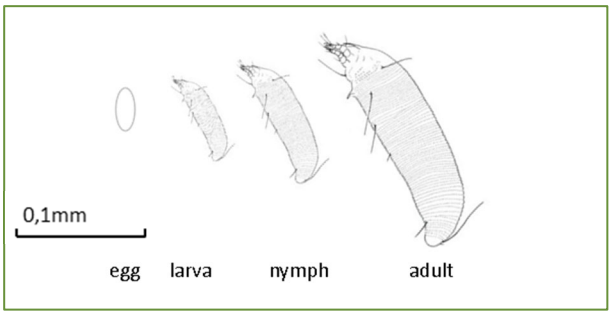


Figure 9: Life cycle of Eriophyoid mites.

Adults have only 2 pairs of legs and their body is either fusiform or vermiform. Their average body length is 0.2 mm (invisible to the naked eye). Observation of eriophyoid mites is possible with a stereo microscope at 25 times magnification. The use of a microscope is required for the identification of the mites at species level.
Eriophyoid mites live in colonies as free living mites (vagrant species) or gall-forming mites (gall mites). They are specific to their host plant: 80% of the eriophyoid species are reported on only one host plant species, 95% on one host plant genus and 99% on one host plant family.

RASPBERRY LEAF AND BUD MITE
PHYLLOCOPTES GRACILIS

Severe infestations may induce a general loss of vigour of the canes and a decreased yield. These mites are very small and invisible to the naked eye. This can make it very difficult to detect their presence on the crop before symptoms appear.


Leaf damage


Leaf damage


Fruit damage

DAMAGE
- yellow blotches on the upper side of leaves
- crinkled leaves after severe infestation
- uneven ripening of the berry, pale spots, dried drupelets or malformed fruits
- possible confusion with symptoms caused by ultra-violet radiation (sunburn)

MAIN HOST PLANTS
- *Rubus* ssp., including wild and cultivated raspberry and blackberry

EGG
- round, not larger than 50 µm, white or pale yellow

ADULT
- body length: 115-130 µm
- fusiform
- 2 pairs of legs
- colour: light yellow to dark yellow in winter

max. 0.13 mm

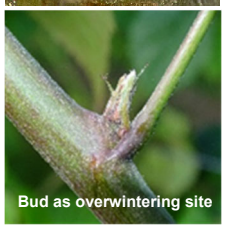
BLACKBERRY MITE / REDBERRY MITE

ACALITUS ESSIGI

A. essigi induces uneven ripening of the fruit, called 'redberry disease'. Physiological processes may also induce this, but the colouration of the drupelets is then reversed. These mites are very small and invisible to the naked eye. This can make it very difficult to detect their presence on the crop before symptoms appear.

Fruit damage

Mites hidden between bud scales



Bud as overwintering site

DAMAGE

- uneven ripening of the fruits
- possible confusion with symptoms caused by ultra-violet radiation (sunburn)

MAIN HOST PLANTS

- *Rubus* ssp., including wild and cultivated blackberry

EGG

- round, not larger than 50 µm, white or pale yellow

ADULT

- body length : 115-130 µm
- fusiform
- 2 pairs of legs
- color: white or light yellow

max. 0.14 mm

BLACKCURRANT GALL MITE

CECIDOPHYOPSIS RIBIS

This Eriophyoid mite species is probably the major pest of blackcurrant worldwide. It produces abnormal and irregular growth of buds and is also responsible for the transmission of the blackcurrant reversion virus (BRV).

Damage symptoms

DAMAGE

- abnormal and irregular growth of the buds
- drying of infested buds
- reduced leaf and flower development
- malformed leaves

MAIN HOST PLANTS

- Grossulariaceae: blackcurrant (*Ribes nigrum*), redcurrant (*Ribes rubrum*), gooseberry (*Ribes uva-crispa*), *Ribes alpinum*, *Ribes spicatum*

EGG

- round, not larger than 50 µm, white or pale yellow

ADULT

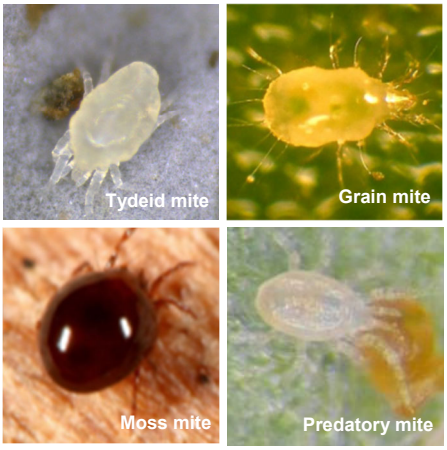
- body length: 230-240 µm
- fusiform
- 2 pairs of legs
- colour: light yellow

max. 0.24 mm

2.4. OTHER MITES

Other mites generally do not cause damage in crops, except in case of a major infestation. Even then they only rarely cause damage.

Other (non-damaging) mites:
Tydeid mites (Tydeidae)
Grain mites (Acaridae - Tyrophagus spp.)
Moss mites (Orbatida)
Siteroptid mites (Siteroptidae)
Bryobid mites (Bryobidae)
False spider mites (Tenuipalpidae)
Predatory mites (Phytoseiidae)



3. Plant defence

Plants have defence mechanisms to counteract attacks from herbivores. Plants recognize herbivore damage through chemical and mechanical signals. Plant hormones are involved in the chemical signalling pathway.

The stress hormones salicylic acid (SA) and jasmonic acid (JA) have emerged as the major signalling hormones that trigger defence responses in plants. The responses are plant- and pest-specific. The response can come directly from the plant upon induction, but herbivores can also make use of the plants' defence system for their own benefit (Figure 10).

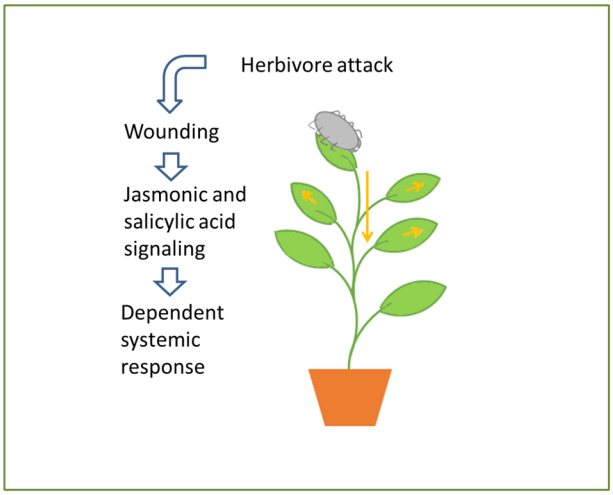


Figure 10: Stress hormone response in plants upon herbivore attack.

3.1. AZALEA

Azalea cultivars differ in susceptibility to the broad mite (*Polyphagotarsonemus latus*). 'Elien' is a resistant cultivar, 'Nordlicht' is very susceptible and 'Mme. Kint' has intermediate susceptibility. Salicylic acid (SA) content was analysed in the leaves of mite-infested azalea. Figure 11 shows high levels of SA in 'Nordlicht', lower levels in 'Mme. Kint' and almost no SA in 'Elien'. Because the amount of SA correlates with the presence of the mites it is assumed that the high levels of SA in susceptible azalea cultivars are induced by the mites.

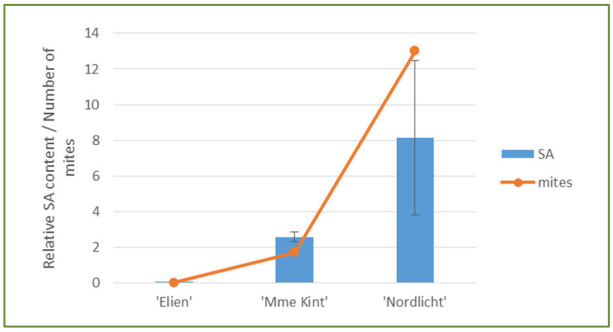


Figure 11: Susceptibility of azalea cultivars to broad mite. Levels of the stress hormone salicylic acid (SA) rise with number of mites.

3.2. RASPBERRY

Raspberry is susceptible to the two-spotted spider mite (*Tetranychus urticae*). Raspberry cultivars also differ in their response to spider mites. In different tests we observed that the cultivars 'Polka' and 'Tulameen' are susceptible, 'Maravilla', 'Esperanza' and 'Riviera' have an intermediate resistance, and 'Carmina' is more resistant. In 'Carmina' it was observed that jasmonic acid (JA) levels drop after mites infest the plant. Figure 12 shows this drop. JA levels are high before the introduction of spider mites, but decrease one week after the release of the mites.

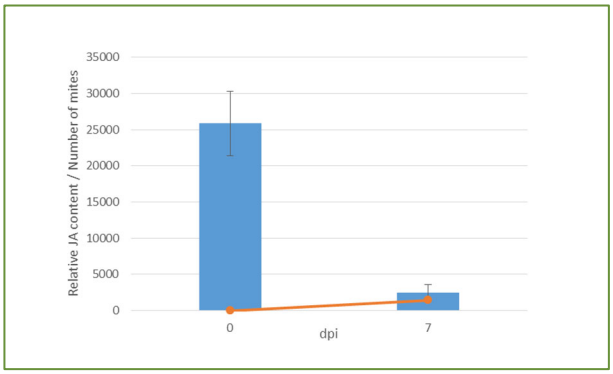


Figure 12: Jasmonic acid (JA) levels drop on raspberry 'Carmina' plants infested with two-spotted spider mite.

3.3. STRAWBERRY

Susceptibility to *T. urticae* in strawberry is highly dependent on the cultivar (Figure 13). 'Amesti' and 'Marquis' represented the extremely resistant and susceptible cultivars, respectively. Interestingly, the enhanced resistant response of 'Amesti' was observed 21 days after infestation (dpi) but not at 7 dpi. To ascertain the contribution of the different defensive pathways in these observations, phytohormones were measured 7 and 21 dpi. No changes were observed for 'Amesti', the most resistant cultivar. However, in 'Marquis' JA was downregulated at 7 dpi and SA was upregulated at 21 dpi. Further experiments confirmed that *T. urticae* can manipulate 'Marquis' to inhibit its defensive pathways and that, given that neither JA nor SA were upregulated in 'Amesti', the resistance in this cultivar should be attributed to alternative defence pathways.

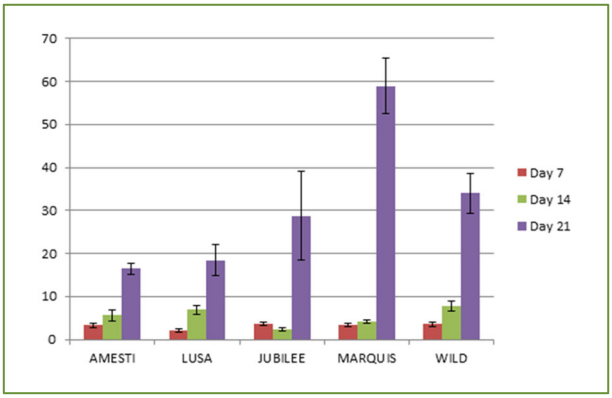


Figure 13: *Tetranychus urticae* population densities (number of motiles and eggs per plant/average cultivar leaf area) at different time points after infestation (dpi) on five different strawberry genotypes including a wild type (n=5). Plants were infested with 4 adult females at the onset of the assay.

3.4. CITRUS

Citrus are susceptible to different mites, including the broad mite (*Polyphagotarsonemus latus*). Results show that the defensive response observed in the three rootstocks considered (Figure 14) is the opposite of what was known for *T. urticae*. This result confirms the specificity of the plant response to herbivory.

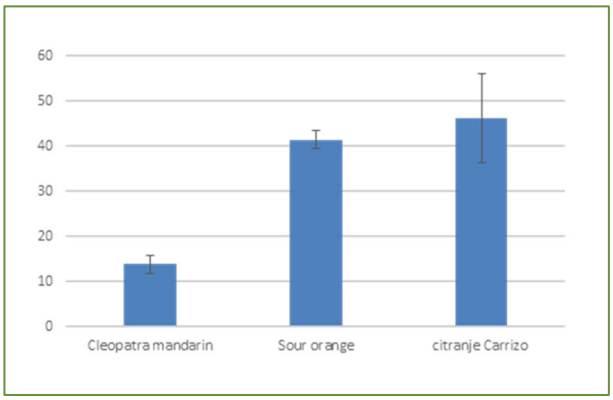
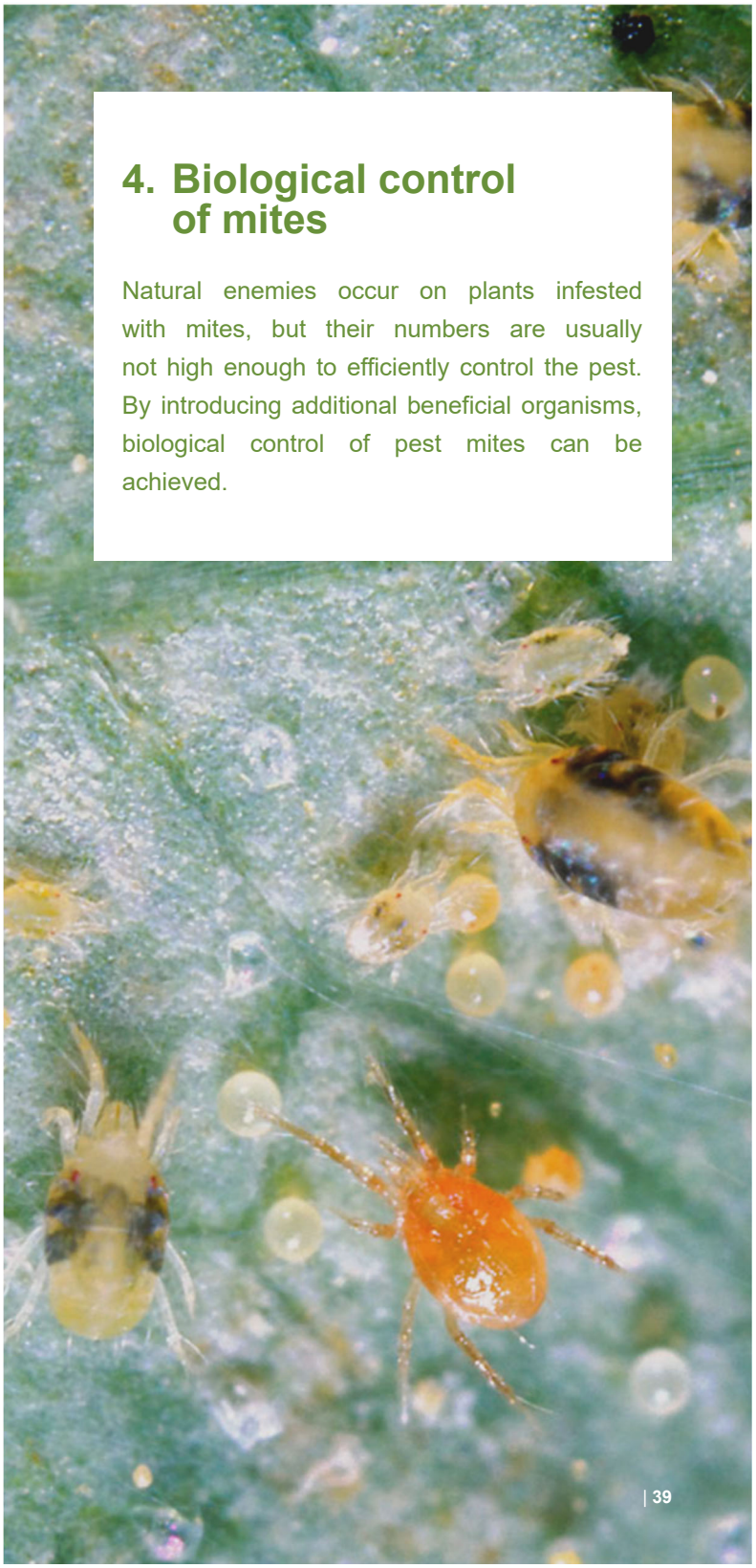


Figure 14: *Polyphagotarsonemus latus* population densities (number of motiles per plant) 21 dpi on three different citrus rootstocks (n=5). Plants were infested with 4 adult females at the onset of the assay.



4. Biological control of mites

Natural enemies occur on plants infested with mites, but their numbers are usually not high enough to efficiently control the pest. By introducing additional beneficial organisms, biological control of pest mites can be achieved.

4.1. BENEFICIALS FOR THE CONTROL OF PEST MITES

SPIDER MITES

Phytoseiulus persimilis	predatory mite
Neoseiulus californicus	predatory mite
Amblyseius andersoni	predatory mite
Feltiella acarisuga	gall midge
Macrolophus pygmaeus	predatory bug
Paecilomyces fumosoroses	fungus

TARSONEMID MITES

Amblyseius swirskii	predatory mite

ERIOPHYOID MITES (TESTS ONGOING)

Amblyseius swirskii	predatory mite
Euseius gallicus	predatory mite
Amblyseius montdorensis	predatory mite
Amblydromalus limonicus	predatory mite

Note - not all of the species may be available in the UK

4.2. PREDATORY MITES
Phytoseiidae

Predatory mites are relatively small mites (0.3 mm) and can be categorised into 4 types depending on their diet (Figure 15).

Type I: spider mite specialists

Predatory mites of type I are real spider mite specialists. As they exclusively feed on spider mites, they cannot survive without them. They can very quickly build a large population and thus suppress outbreaks. *Phytoseiulus persimilis* is the most commonly used type I mite. This is a remarkable red predatory mite, which eats all stages of spider mites (from egg to adult). Optimal control occurs at 25-28°C. This predatory mite is only available in bottles with a dosage plug and cannot be introduced preventively. For the treatment of outbreaks it is recommended to disperse the mites; for total control of the crop a blowing device is best used. They are capable of migrating far into the crop in search of their prey.

Type II: moderate spider mite specialists

Predatory mites of type II are moderate spider mite specialists. They primarily feed on spider mites, but can also survive on pollen and survive periods with less spider mites. They are ideal for preventive introduction, but are less capable of controlling outbreaks. *Neoseiulus californicus* is a commonly used type II predatory mite. It is a white, translucent predatory mite with a

beige-brown marking on its back. They prefer spider mite nymphs, but the adult females eat all stages. In case of absence of spider mites they also eat thrips and pollen, but they do not migrate far into the crops. They are very active at 20-33°C and are ideal to introduce preventively or routinely by using breeding sachets.

Type III: generalists

Predatory mites of type III are generalists. They feed mainly on thrips, whitefly and tarsonemid mites, but can also feed on other predatory mites and sometimes spider mites. They can easily use pollen to survive and build a population. Type III mites can be introduced preventively before the pest is in the crop. However they are often dominant and can outcompete predatory mites of type I and type II when spider mite pressure is low. Therefore they should not be introduced in combination with these predatory mites.

Figure 15: Predatory mites. **Left top:** *Phytoseiulus persimilis*. **Right top:** *Neoseiulus californicus*. **Left bottom:** *Amblyseius swirskii*. **Right bottom:** *Euseius gallicus*.

To this type belong (among others):

- *Amblyseius swirskii* is a white-beige predatory mite introduced to control thrips, whitefly and tarsonemid mites and to a lesser extent spider mites. They are most active at higher temperatures and should not be introduced at temperatures lower than 15°C.
- *Amblyseius andersoni* is a predatory mite which feeds mainly on pest mites such as tetranychid and eriophyoid mites. It can also feed on thrips and pollen and is the perfect mite for use at cooler temperatures.
- *Neoseiulus cucumeris* is a beige predatory mite which is mainly introduced to control thrips. They are mainly active between 20-25°C for a few hours per day. Under 10°C they are not active at all.
- *Amblydromalus limonicus* a white, translucent predatory mite introduced to control thrips and whitefly. They are active at 13-30°C.

Type IV: complete generalists

Predatory mites of type IV are pure generalists. Although they feed on diverse pests, they prefer to eat pollen. Therefore it is important to introduce them in large numbers. They can very easily build a population on pollen and have a strong instinct to migrate and search for pests. They are ideal for preventive introduction. These predatory mites appear by nature in greenhouses. The *Euseius*-predatory mites belong to this type IV, of which *Euseius gallicus* is commercially available. This is a yellow-beige predatory mite, which can be introduced to control thrips and whitefly. When a pest appears in the greenhouse, additive feed (pollen) should be minimised. They are active at 10-32°C.

Soil-dwelling predatory mites

Soil-dwelling predatory mites are up to 3 times the size of crop predatory mites. They can be found in and on the soil, where they control pests of the soil or pests of which a part of the life cycle occurs in the soil.

The following predatory mites belong to the group of soil-dwelling predatory mites (Figure 16):

- Brown predatory mites which feed on pupae of thrips and larvae of Sciara and springtails. These soil-dwelling predatory mites can survive up to 7 weeks without food. They are active at 15-25°C. There are 2 important types: *Stratiolaelaps scimitus* (formerly *Hypoaspis miles*) mainly lives in the top 4 cm of the soil, while *Gaeolaelaps aculeifer* (formerly *Hypoaspis aculeifer*) is usually found deeper in the soil.
- *Macrocheles robustulus* is a pale brown, very active soil dwelling predatory mite that lives in the top layer of the soil. It feeds on pupae of thrips, eggs, larvae and pupae of *Sciara* and larvae of springtails. It requires a minimum temperature of 15°C to be effective.

Figure 16: Soil-dwelling predatory mites. **Left:** *Stratiolaelaps scimitus.* **Right:** *Macrocheles robustulus.*

Introducing predatory mites into the crop

Predatory mites are delivered in paper sachets or bottles of variable sizes with a dosage plug. They are transported in combination with an inert carrier material (bran) and prey mites as feed to survive transport and storage (Figure 17).

When the predatory mites arrive, it is best to introduce them immediately into the crop as this will maximise their effectiveness. If immediate introduction is not possible, the predatory mites are best stored at 12-14°C and never longer than 3 days. When storing bottles, be sure to lay them in a horizontal position. When the bottles are stored upright, the predatory mites have the tendency to crawl upwards. This results in an uneven spread within the bottle and thus also in the crop(s). Before application, it is recommended to gently roll the bottle for a minute to spread them more homogenously and make the predatory mites more active.

Bran

Mites delivered in bottles can be applied to the crop by hand either in a dispersed way or on certain 'hot-spots', depending on the type of application and the degree of crop infestation.

The predatory mites can also be dispersed mechanically or automatically over the crops by means of blowing devices. Koppert has 3 blowing devices which are currently being used, namely the Mini-Airbug, the Airbug and the Airobug (Figure 18):

- The Mini-Airbug can be carried in 1 hand and blows the predatory mites up to 2 m into the crop, ideal for treatments of outbreaks or smaller areas.

Figure 17: Packaging predatory mites. **Left:** paper sachets. **Right:** bottle.

Figure 18: Blowing devices Koppert and Biobest. **Left top:** Mini-Airbug. **Right top:** Airbug. **Left bottom:** Airobug. **Right bottom:** Nutrigun.

- A larger version of this is the Airbug. It is carried around the persons' midriff with a belt. The Airbug can blow the mites up to 4 m into the crop.
- The Airobug is a fully automatic device with a self-propelled conductor that can ride on a monorail. With this system the predatory mites are blown into the crops up to 12 m on both sides of the device.

When predatory mites are being introduced into the crop, the content of the bottle is poured into the dispenser box with holes. There are dispenser boxes with different sizes of holes, which determine the volume, and thus number of predatory mites, which are spread over a certain time interval (ml/minute). The dispenser box is turned by the blowing device and the predatory mites fall through the holes into an airflow created by the fan, which then blows them into the crops.

Adapted blowing devices are available for the dispersal of additional feed (such as pollen or artemia cysts) to support the build-up of populations of predatory mites and other beneficials. The blowing devices from Koppert can be used with an adapted dispenser box with smaller holes. Biobest has an additional device for the dispersal of pollen: the Nutrigun.

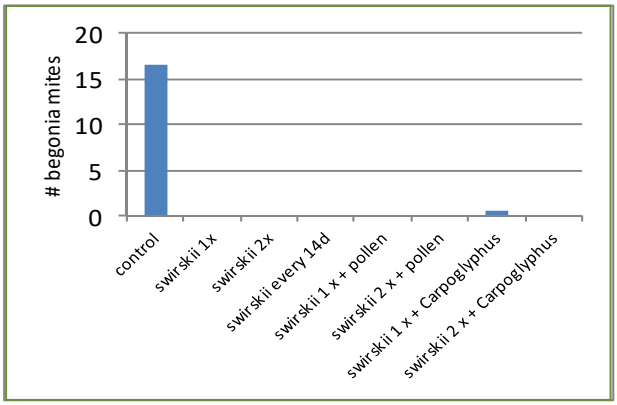
Breeding sachets

Breeding sachets are provided with a hook to hang them (manually) in crops. Each sachet will result in about 4 to 6 weeks supply of predatory mites. The breeding sachets are preferably not used in systems with overhead watering sprinklers, because this causes the sachets to get wet, which kills the mites inside the sachet. Breeding sachets are not available for all predatory mites. The following predatory mites are currently available:

- *Amblyseius swirskii*
- *Amblyseius andersoni*
- *Neoseiulus californicus*
- *Neoseiulus cucumeris*

4.3. EFFICIENCY AND SUSTAINABLE APPLICATION

To control broad mites in azalea, 2 experiments with predatory mites were conducted during the Uniforce project. In the first trial a control treatment was compared to 7 different treatments with *Amblyseius swirskii:* single treatment, two treatments with two weeks in between, treatment every two weeks, single or double treatment and additionally pollen or *Carpoglyphus* feeding mites every two weeks. All swirskii treatments gave good control results (Figure 19). In a later stage of the trial, the swirskii mites were found in the control treatment and managed to curatively control the broad mites there as well. This shows that *Amblyseius swirskii* is capable of both preventing and controlling existing populations of broad mites in azalea.



Figuur 19: Number of broad mites 5 weeks after first treatment with predatory mites.

In a second trial all commercially available predatory mites, with and without pollen feed, were evaluated against broad mites. We could clearly see an enhanced population build-up in the treatments with pollen feed compared to those without pollen feed. Treatments with *swirskii* and *cucumeris* showed good control of broad mites, other treatments showed an insufficient result. Treatments with a dash were infested with other predatory mites and therefore removed from the results. The following table gives an overview of the results.

% BROAD MITES COMPARED TO START FOR DIFFERENT TREATMENTS WITH COMMERCIALLY AVAILABLE PREDATORY MITES

Treatment	+ 1 month	+ 2 months
control	62%	224%
swirskii 1x	50%	51%
swirskii 2x	**21%**	**36%**
swirskii every 14d	59%	**34%**
swirskii 1x + pollen every 14d	84%	**34%**
swirskii 2x + pollen every 14d	**17%**	**8%**
gallicus every 14d + pollen every 14d	141%	-
montdorensis every 14d	34%	56%
montdorensis 2x + pollen every 14d	63%	86%
californicus every 14d	188%	161%
californicus 2x + pollen every 14d	81%	-
cucumeris every 14d	158%	**41%**
cucumeris 2x + pollen every 14d	**37%**	**19%**
andersoni every 14d	184%	131%
andersoni 2x + pollen every 14d	123%	91%
limonicus every 14d	117%	83%
limonicus 2x + pollen every 14d	129%	-
degenerans every 14d	137%	-
degenerans 2x + pollen every 14d	107%	-

4.4. SIDE EFFECTS

To quantify the impact of commonly used acaricides on swirskii predatory mites, a comparative field trial was set up. The following table gives an overview of the used products. The trial was conducted in the spring of 2018, during a very warm and sunny period. Three days after spraying, no impact of the chemicals on the predatory mites was visible (except for Decis), this could have been caused by the warm and sunny weather during which the predatory mites were hidden deeper in the crop and had less chance of direct contact with the spray (Figure 20). Not all products are available in the UK.

ACTIVE SUBSTANCE AND ABBREVIATION OF THE USED ACARICIDES

Product	Active substance	Abbreviation
Control	Water	Co
Decis	Deltamethrin	De
Vertimec	Abamectin	Ve
Milbeknock	Milbemectin	Mi
Nissorun	Hexythiazox	Ni
Masai	Tebufenpyrad	Ma
Carex	Pyridaben	Ca
Floramite	Biphenazate	Fl
Kanemite	Acequinocyl	Ka
Kumulus	Sulphur	Ku
Bonzi	Paclobutrazol	Bo

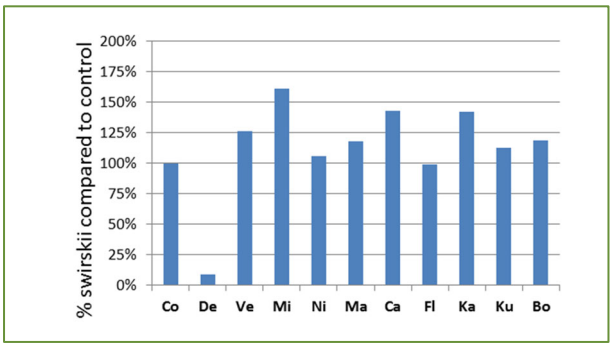


Figure 20: Effect of acaricides on swirskii predatory mites, 3 days after treatment.

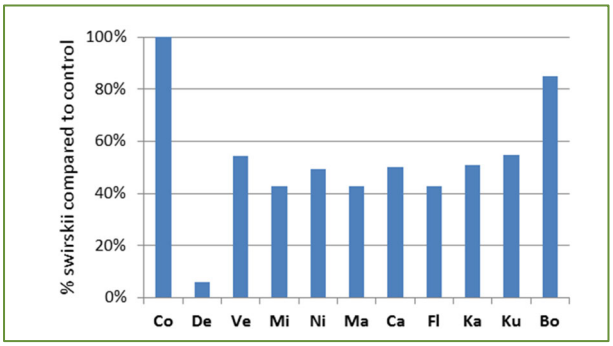


Figure 21: Effect of acaricides on swirskii predatory mites, 14 days after treatment.

During a second evaluation, 2 weeks after application, all products (except Bonzi) caused a population reduction among swirskii mites of over 50%, compared to the control treatment (Figure 21). Caution is advised when using those products in combination with swirskii mites.

To evaluate the residual effect of products, new swirskii mites were introduced 14 days after the spray treatment. Figure 22 shows that for most products there is still a clear negative effect on the population of swirskii, with populations at about 50% compared to the control. Only for Milbeknock, Nissorun and Bonzi was the population greater than 70%. So when re-introducing swirskii mites 14 days after a spray application, this should be taken into account.

One month after spray application predatory mites were introduced again. Figure 23 clearly shows that there is no more residual effect for most products, only the treatment with Carex resulted in a population of only 70% as compared to the control, and Masai and Vertimec were below 80%. One month after treatment can thus be considered safe for re-introducing swirskii mites. However it should be taken into account that this experiment was conducted during a warm and sunny period, which favours the break down of the chemicals. A replication of this experiment under winter circumstances will probably result in a longer residual effect on predatory mites. Caution is advised.

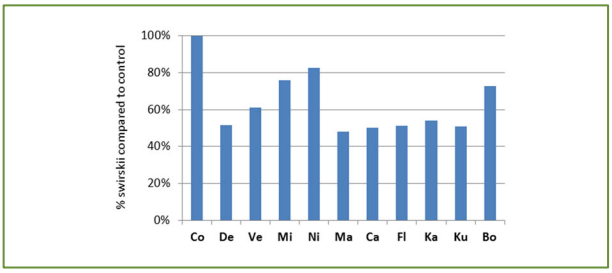


Figure 22: Residual effect of acaricides against swirskii 14 days after spray application.

Figure 23: Residual effect of acaricides against swirskii 1 month after spray application.

4.5. OTHER BENEFICIALS

Predatory mirid: *Macrolophus pygmaeus*

Macrolophus pygmaeus is a pure generalist. This means that it feeds on different mites and insects, but also shows cannibalism when the population is large. The mirid is green with long legs and typical brown eyes from which a black line emerges. It has green wings with a black dot in the middle and is 3 mm long. The nymphs are first yellow and then green, but without black markings. Both nymphs and adults are predators. In high densities *Macrolophus* can damage the plant. Therefore populations should be monitored closely.

Introduction of predatory mirids into the crop

Predatory mirids are delivered in bottles as nymphs and adults, in combination with a carrier product (Figure 24). It is recommended to turn and roll the bottle before use. The content can be dispersed on leaves by hand or poured into dispenser boxes. Make sure to make piles of minimum 50 individuals in a layer of max. 1 cm. The bottles can be stored horizontally at 8-10°C for 2 days in the dark.

Figure 24: Predatory bug. **Left:** Bottle. **Right:** dispenser box.

OTHER BENEFICIALS

Gall midge: *Feltiella acarisuga*

The gall midge *Feltiella acarisuga* is small (2 mm), brown-pink, winged and hairy. The nymph is first pale yellow, but becomes orange-brown with white spots later on. During pupation they spin a cocoon. They can easily track down a spider mite outbreak (Figure 25).

Introduction of gall midges into the crop

Gall midges are delivered in bottles as pupae in a carrier product. These beneficials can simply be introduced in the greenhouse by opening the bottle; the carrier in bottle should not be poured out. You can place the bottle on the floor or hang it in between the crops on a string. Preferably use fishing line, to protect the gall midge pupae against ants. Place the bottle close to the pest outbreak.

Figure 25: Gall midges. **Left:** Nymph of *Feltiella acarisuga*. **Right:** Inside of a bottle for the introduction of gall midges.

OTHER BENEFICIALS

Fungus: *Paecilomyces fumosoroseus*

The spores of *Paecilomyces fumosoroseus* stick to the pest. After germinating, this fungus penetrates the skin or natural openings, e.g. the mouth, and kills the pest.

Introduction of parasitic fungus into the crop

Paecilomyces fumosoroseus is available in a resealable package of 500 g. This fungus first needs to be dissolved in a bucket of water at about 20°C. Over an hour the water must be stirred regularly until a thin mush develops. Let this mush settle and then pour the top water into the ready-to-use barrel. Ratio of powder to water: 100 g powder in 100 l water. For best results, use 1000 l/ha for young or small crops and 2000 l/ha for large crops. The product keeps unopened for 12 months in a dry place at 2-6°C .

5. Conclusion

Mite pests are a hazard to many different crops all over the world. This guide gives an overview of which mites form the biggest risk in azalea, soft fruit and citrus crops, how they can be monitored, how the plant responds to these mite attacks and which control methods exist.

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