# SCEPTREPLUS

## Final Review Report

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| Trial code: | SP 34 |
| Title: | Control of Tomato Russet mite (review of control measures and efficacy trials) |
| Crop | Tomato |
| Target | Tomato Russet Mite (TRM), *Aculops lycopersici* (Eriophyidae) |
| Lead researcher: | Dr. Charles Whitfield |
| Organisation: | NIAB East Malling Research |
| Period: | Start: 1st Aug 2018 Duration: 12 months |
| Report date: | August 2019 |
| Report author: | Charles Whitfield, with input from Adam Peter |
| ORETO Number: (certificate should be attached) | N/A |

I the undersigned, hereby declare that the work was performed according to the procedures herein described and that this report is an accurate and faithful record of the results obtained

02/10/2019……
Date

Charles Whitfield
Authors signature

## Review Summary

### Introduction

The Tomato Russet Mite *Aculops lycopersici* (Eriophyidae) (TRM) is a common and significant pest of tomato or other solanaceous crops in mainland Europe and many others area around the world, but has become an increasing problem in UK tomato production. Unlike other Eriophyid mites the TRM is oliophagous and is reported to survive on a range of solanaceous plants (nightshades) (Rice and Strong, 1962, Bouneb, 2014) and also plants in other families, e.g. *Convolvulus arvensis* (field bindweed), wild blackcurrant, wild gooseberry and blackberry (Duso et al., 2010). Although damaging outbreaks are sporadic, its fast reproductive rate and the challenges of spotting the initial stages of an infestation mean that populations can build up unnoticed, causing significant damage to plants and fruit. The visible symptoms of TRM infestation are a characteristic discolouration of the stems to a brown/golden colour, shrivelling and browning of leaves, flower drop, and fruits exhibiting russeting. Severe infestations can lead to death of the plant. Even relatively minor infestations can cause flower-drop, reduced fruit size, and fruits with visible TRM damage (russeting) which are unsaleable; consequently, the pest can cause significant financial loss to growers. A Dutch agronomist reported that TRM can reduce yields by 10% per $m^2$. The damage symptoms are the result of mites feeding from the plant epidermal tissues, inhibiting photosynthesis. Spotting the pest and controlling it before populations are high enough to cause visible damage is essential. In the UK, the pest is still sporadic and locally not important every year. However, anecdotally, incidence of this pest is increasing. TRM is most often a problem during the warmer months, as its reproductive rate is highest at higher temperatures and lower humidity. The warmer and drier climate in the south and east of the UK are likely to lead to the pest being more common.

Current control options are limited, and growers mainly rely on sulphur-based products or conventional acaricides which can upset the biocontrol options for other pests. In addition, reports from The Netherlands suggest that abamectin is no longer effective. Use of natural enemies to manage TRM has so far been unsuccessful, partly due to the tomato plants' glandular trichomes which hamper movement and establishment of predators (Duso et al., 2010). The TRM's small size allows it to hide within the dense canopy of the glandular leaf hairs, protecting it from predators and providing shelter from sprays. The mites may also shelter in small crevices on the plant surface or behind support wires or other structures (van Houten et al., 2013). The industry urgently requires new IPM compatible strategies to reduce the effects of TRM.

This document reviews current and potential new control strategies for UK tomato growers. A number of stakeholders including growers, agronomists, and Plant Protection Product manufacturers and suppliers were interviewed to provide current industry practices in the UK and The Netherlands. Industry reports, scientific publications, and commercial sources were reviewed for current and potential control strategies used in and outside the UK. The aim of this review is to highlight methods which are compatible with tomato production IPM programmes, and could be used in the UK.

## Summary

The key findings of this review are:

- Cultural control: regular monitoring for TRM is essential to identify outbreaks of the pest before the populations get too difficult to control. Small outbreaks can be controlled using biopesticides and sulphur products. Staff should be **trained** to scout for TRM using a 20x hand lens. A microscope may also be used to confirm the presence of the mites on leaf surfaces. Scouts should continue monitoring infested plants after spraying to assess for effectiveness of the spray.
- Biological control: currently there are no suitable predators to control TRM in the UK. Although there are several species of predatory mites that could be used, none are commercially available in the UK.
- Bioinsecticides: there are several biopesticides that are highly effective at controlling TRM populations. Maltodextrin (e.g. Majestik) and fatty acids (e.g. Flipper) work well, especially when combined with sulphur-based products (e.g. Microthiol Special). Good spray coverage achieved by targeted spray application is key to getting good results. Use adjuvants where appropriate to improve spray coverage on plant surfaces. TRM populations are often highest just in front of where symptoms are visible on the plant.
- Conventional insecticides: abamectin products are available for use in the UK and work effectively to control TRM. Their use should be as a last resort as they will disrupt predatory mites and other biocontrol agents. Reports from The Netherlands suggest that TRM may have resistance to abamectin, but this is not yet confirmed.


## Next Steps

A number of products have been identified which are used outside of the UK to control TRM (Table 1). These products could be suitable for use by UK tomato growers but would require trials to ascertain their effectiveness and registration.

**Table 1: summary list of candidate active ingredients or products to assess for IPM-compatible control of *Aculops lycopersici* in UK tomato production.**

| Type | Active ingredient | Comments |
|---|---|---|
| Bioinsecticide | Milbemycin A3 and A4 | Milbemectin is available in other EU countries, including Germany and The Netherlands, but not in the UK. It is also used in Australia and the USA. Reported as highly effective against all TRM life stages. May have some negative effects on *Macrolophus*, but is much less damaging than abamectin. |
| Bioinsecticide | azadirachtin A | Known to be effective at controlling TRM and other mites. Used in other EU countries, and Australia, USA, and India for TRM control. May have some negative effects on *Macrolophus*. |
| Bioinsecticide | *Beauvaria bassiana* | Reported as being effective at controlling TRM populations. Research is required to find the optimal methods for using *B. bassiana* products in UK tomato production, specifically the optimal temperature and humidity for the |

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|---|---|---|
| | | entomopathogenic fungi, and if there is significant benefit in applying *B. bassiana* in combination with physical-acting products, e.g. maltodextrin. |
| Bioinsecticide | *Hirsutella thompsonii* | e.g. MycoHit and NO-MITE are used in India, and may be suitable for use in the UK. |
| Bio-agent | *Amblyseius fallacis* | Used in the USA and Canada for control of TRM and spider mites in tomato crops. It is not available in the EU, nor is it native to the UK. |
| Acaricide | Floramite 240 g / l bifenazate | An EAMU was issued in 2018 for this product to be used for the control of two spotted spider mites in tomato. Currently there is no evidence on whether it will control TRM. |

Methods of controlling TRM currently available in the UK could be improved. The following are suggestions of how TRM control in the UK could be improved.

- Training for crop pest scouts to improve spotting of TRM using 20x hand lens and/or microscopes before the pest population gets too high. TRM is visible on leaves using a 20x hand lens. Hold the leaves up to the light and inspect the underside of leaves where the stem meets the leaf and work up towards the leaf tip.
- A monitoring protocol should be developed to improve scouting efficiency, and population thresholds for spray applications should be calculated.
- Pest risk and development models for the UK should be developed and tested to guide spray programmes for controlling TRM.
- Assess spray applications methods to find the optimal method of spraying TRM. Assess the use of adjuvants, targeted spraying, and optimal spray intervals for glasshouse environmental conditions (related to pest development models).

### Take home message(s)

- Interplanting may increase the risk of TRM outbreaks. The mite does not survive below 8 °C, so break periods during the winter combined with removal of all plant material and sterilising the glasshouse should eliminate TRM.
- Effective and thorough monitoring by trained personnel using a 20x hand lens and/or microscope is the key to controlling TRM. Marking plants and the height of the TRM symptoms can assist with long term monitoring and TRM activity. After spraying plants should be assessed for surviving TRM, and follow-on sprays should be applied as required.
- Targeted spraying with good coverage will improve the effectiveness of the products used.

## Review

### Introduction

The Tomato Russet Mite *Aculops lycopersici* (Eriophyidae) (TRM) is a common and significant pest of tomato or other solanaceous crops in mainland Europe and many other areas around the world, but has become an increasing problem in UK tomato production. Unlike other Eriophyidae mites the TRM is oliophagous and is reported as surviving on a range of solanaceous plants (nightshades) (Rice and Strong, 1962, Bouneb, 2014) and also plants in other families, e.g. *Convolvulus arvensis* (field bindweed), wild blackcurrant, wild gooseberry and blackberry (Duso et al., 2010). Although infestations are sporadic, its rapid reproductive rate and the challenges of spotting the initial stages of an infestation mean that populations can build up unnoticed, causing significant damage to plants and fruit. The visible symptoms of TRM are a characteristic discolouration of the stems to a brown/golden colour, shrivelling and browning of leaves, flower drop, and fruits exhibiting russeting. Severe infestations can lead to death of the plant. Even relatively minor outbreaks can cause flower-drop, reduced fruit size, and fruits with visible TRM damage (russeting) which are not saleable; consequently, the pest can cause significant financial loss to growers. The visible damage symptoms are the result of mites feeding from the plant epidermal tissues inhibiting photosynthesis. Spotting the pest and controlling it before the populations are high enough to cause visible damage is essential. In the UK, the pest is still sporadic and locally not important every year. However, anecdotally, the incidence of this pest is increasing. TRM is most often a problem during the warmer months, as its reproductive rate is highest at higher temperatures and lower humidity. The warmer and drier climate in the south and east of the UK are likely to lead to the pest being more common.

Current control options are limited, and growers mainly rely on sulphur-based products or conventional acaricides which can upset biocontrol options for other pests. Use of natural enemies for TRM has so far been unsuccessful, partly due to the tomato plants' glandular trichomes which hamper movement and establishment of predators (Duso et al., 2010). The TRM's small size allows it to hide within the dense canopy of the glandular leaf hairs, protecting it from predators and providing shelter from sprays. The mites may also shelter in small crevices on the plant surface or behind support wires or other structures (van Houten et al., 2013). The industry urgently requires new IPM compatible strategies to reduce the effects of TRM.

### Target Description and Life-cycle

With the common name "tomato russet mite" (TRM) or "tomato mite", *Aculops lycopersici* is part of the Eriophyidae family of mites (commonly known as gall mites, although the TRM does not cause galls). Adults are fusiform (i.e. tapered at both ends or spindle shaped) and typically range from 150 to 200 µm in length. The mites' extremely small size make them difficult to identify even with a hand lens. Figure 1 shows the difference in size between the TRM and the two-spotted spider mite.


**Figure 1: showing a two-spotted spider mite (*Tetranychus urticae*) (centre) surrounded by a number of tomato russet mites *Aculops lycopersici* which are visible as small white spindle shaped organisms. The insert (right) shows a close up image of *A lycopersici* with a 30 µm blue scale bar. Photo by J. van Arkel (University of Amsterdam) (Glas et al., 2014).**

Eggs hatch within 2 days of laying at room temperature (Bailey and Keifer, 1943). The larval stage lasts 1 day, and the nymphal stages 2 days. The TRM can double its population in three days at 25 °C (Fischer and Mourrut-Salesse, 2005). It has been observed by Rice and Strong (1962) that the complete life-cycle is 6.5 days at 21 °C and 30% RH. At very high temperatures (32 °C) TRM requires low relative humidity for survival. Optimal conditions for the TRM were found to be 26.7 °C and 30% RH (Rice and Strong, 1962). More recent studies have measured TRM development at a range of temperatures from 8 °C to 39 °C, at 55 %RH (Alazzazy and Alhewairini, 2018). Mite development at either 8 °C or 39 °C was so slow (or ceased altogether) that the adults died, but they were able to survive and reproduce between 11 °C and 36 °C. The highest rate of population increase was at 32 °C, where the population multiplied 18.14 times in a generation time of 14.45 days. At 11 °C the rate of population increase lowered to 4.25 times in a generation time of 26.38 days. Alazzazy and Alhewairini's studies were all conducted under laboratory conditions.

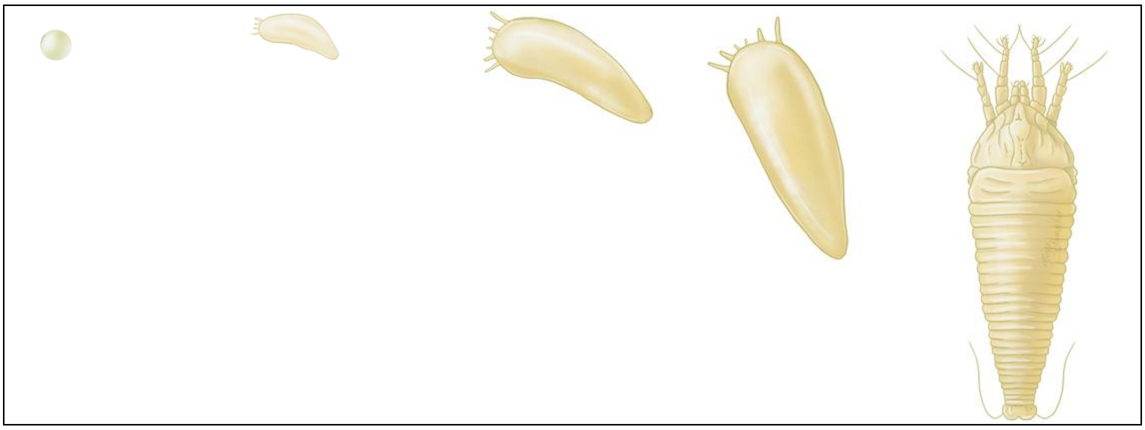

**Figure 2: Aculops lycopersici life cycle. Left to right: egg, larva, first instar nymph, second instar nymph,  adult. Images from (Koppert Biological Systems, 2018).**

## Symptoms and Identification

Eriophyid mites are known to disperse by crawling, wind, and by hitching a ride on other organisms (Sabelis and Bruin, 1996, CABI, 2019b).
Adult females are usually highly abundant on plants with visible symptoms. Although the mites are extremely small they can be seen with a x14 hand lens, but identification is easier with the use of a stereomicroscope (x30). TRM populations usually develop at the base of the plant and move upwards, feeding on green tissues. Often the highest number of mites can be found just above the visible signs of tissue damage (Kay, 1986). As the population density of TRM increases on a plant, the mites increase their feeding rate, which can ultimately lead to the death of the plant.

**Figure 3. Left: Individual *Aculops lycopersici* on tomato leaves. Right: populations of *A. lycopersici* on fruit and calyx causing visible symptoms of golden/brown colouration on calyx. Photos courtesy of Neal Ward at BioBest Group.**

**Figure 4: Left: discolouration on tomato stems and dried out leaves caused by *A. lycopersici*. Right: severe russeting on tomato fruit. Photos courtesy of Jasper Hubert at Koppert.**

## Cultural Control and Management

Current IPM-compatible control measures for TRM are only partially effective and acaricides will disrupt the biocontrol of other pests; therefore cultural and management controls are essential to minimise TRM outbreaks.

<u>Physical barriers</u>

The TRM's small size means it relies on other organisms and air currents to disperse. TRM has a wide host range and therefore may be present in the wider environment outside of the glasshouse, particularly on any solanaceous plants during the warmer months. Potentially the mite can enter glasshouses via the ventilation systems and hitching a ride on insects, birds, or people. Meshes at ventilation points may prevent TMR entering the glasshouse by stopping other organisms which are carrying the mite.

Other physical barriers that have been tried or suggested by growers and agronomists include insect glue or grease around the stems of plants which may hinder the mite travelling up the plant and spreading. Scientific studies are required to confirm if meshes or insect glues are effective. These types of barriers may not be practical in commercial glasshouses.

<u>Crop hygiene</u>

Interplanting increases the risk of TRM outbreaks (and other pests and diseases) because continuous cropping provides no opportunities for complete cleaning of the glasshouse. In The Netherlands, interplanting is being used less due to issues with pests. A break period between November and January is advisable to allow all plant material (including weeds) and other debris to be removed from the glasshouse and the application of sterilising solutions. Huwa-San TR50 (containing silver stabilised hydrogen peroxide) has been reported as effective at killing adult and eggs of TRM (Alazzazy and Alhewairini, 2018). Other hydrogen peroxide products or other suitable sterilisers may also be effective.

One grower reported that all staff working in their glasshouses wear clean sets of clothes and boots every day. Each person has three pairs of clothes and boots, which are kept on-site and washed regularly. All trolleys and picking crates are sterilised with hydrogen peroxide before entering the glasshouses. Although the costs are high, this level of sterilisation will reduce the chances of mites, and plant viruses, pathogens, and insects entering the glasshouse area.

<u>Monitoring</u>

Growers and agronomists interviewed for this review emphasised how important thorough monitoring for TRM is for achieving control. Outbreaks spotted early can be controlled, but once TRM has established they can be extremely difficult to contain, and heavily infested plants may have to be removed.

Monitoring new plant material as it enters the glasshouse for symptoms of pests or diseases should be routinely undertaken using a microscope to assess for mites. One grower reported checking 1% of new plant material from propagators but had not yet found TRM on any of these plants, whilst other pests were occasionally spotted.

Monitoring should continue through the growing season, ideally with specific staff trained in spotting TRM symptoms and confirming with a microscope. Regular training of staff to spot pests and diseases is advised. Labelling plants that have been infected with TRM may help keep track of outbreaks over the season.

Moerkens et al. (2018) devised a sampling plan for monitoring TRM. The system utilises a standard smartphone with a magnification lens attached. By taking photographs of the upper surface of leaves, the mean TRM density is estimated using their formulae. The authors determined the optimal number of samples required and the corresponding mite thresholds (tally of mites per sample) for accuracy of the estimate. They concluded that 15 samples would be sufficient in commercial glasshouses, but 20 samples is more accurate.

<u>Crop varietal effects and plant physiology</u>

Trichomes play an important role in the plants' defence against TRM. Tomato varieties with trichomes with higher amounts of 2-tridecanone in the glandular trichomes, are more resistant to TRM attack than other plants (Leite et al., 1999). This and other pest-deterring compounds are found in much higher levels in wild tomato varieties, such as *Solanum habrochaites* (Leite et al., 2001), but to date, there does not appear to be any commercial varieties with levels of 2-tridecanone matching that of wild varieties. In commercial tomato cultivars, the density of trichomes has a surprising effect on TRM. Lower densities of non-glandular trichomes (types II and V) are associated with lower TRM populations. This is attributed to the trichomes providing shelter and a beneficial microclimate for the TRM, which can inhabit spaces under the trichomes, protecting them from predators such as phytoseiids and *Tydeus kochi* (Tydeidae) (van Houten et al., 2013, Aysan and Kumral Nabi, 2018). The cultivars in this study with lower non-glandular trichome densities and lower TRM populations were Grande, H2274, and Dora; cultivars with higher non-glandular trichomes and higher TRM populations were M1103, Jana, and Etna (Aysan and Kumral Nabi, 2018).

It should be noted that one of the interviewees approached for this review commented that var. Piccolo had a slightly higher incidence of TRM, compared to other varieties, but this has not been confirmed in scientific studies.

TRM infestations trigger tomato plant trichomes to wither and collapse, but only where TRM are feeding. This process can be quite extreme, with "massive trichome collapse" observed at TRM densities of 50 adults/$cm^2$ (van Houten et al., 2013). Once this occurs, predatory mites can locate and prey upon the TRM. Unfortunately, because this process is local to the high density TRM population and takes at least a week, the loss of trichomes and subsequent ability of predatory mites to predate TRM does not provide sufficient control of TRM outbreaks.

<u>Crop stress</u>
Water stress is a key factor making tomato plants more susceptible to TRM infestation (Duso et al., 2010), both in terms of the growth rate of the TRM population and the damage caused to the plant (Ximenez-Embun et al., 2017).

There are important interactions between TRM and other pests and diseases of tomato. The presence of large populations of spider mites (*Tetranychus urticae*) on tomato plants inhibits the development of TRM populations, possibly due to the plants' defence against the spider mites limiting the growth of TRM (de Lillo et al., 2018). However, tomato plants previously infested with TRM are more susceptible to spider mites (due to TRM's impact on plant defence systems) (Glas, 2014). In addition, high populations of TRM inhibit the development of *Pseudomonas syringae* pv. *tomato*, due to the plants' defence mechanisms triggered against TRM.

Agronomists interviewed for this review reported that in their experience healthy tomato plants are less susceptible to TRM. Plants with vigorous growth may have a more humid micro-climate, which hinders TRM development.

## *A. lycopersici* Development Models

Currently there are no complete and published population development models for TRM. Developing such a model would be of great benefit to growers, to assist with estimating TRM risk and deciding upon suitable control measures. A prototype simulation model for TRM has been developed (Zhang et al., 2008), but it is not complete.

## Natural Predators and Biological Substances

All growers and agronomists interviewed for this review stated that their preferred option for control of TRM is a biological control agent, particularly a natural predator. To date there are no commercially available successful predators for TRM in the UK, but *Amblyseius fallacis* is used to control TRM in the USA and Canada. The species is not native to the UK. Several other predatory mite species survive well on TRM, but so far, none have led to commercially viable products. In India, there are commercially available entomopathogenic fungi that are reported as successfully controlling TRM.

### Predatory mites

*Amblydromalus limonicus* (a phytoseiid mite) predates on TRM (van Houten, 2013), but does not establish successfully on tomato plants due to the plant's trichomes. The predatory mite can establish on TRM-infested plants that have lost the leaf hairs and will then feed on TRM (Hui and Zhang, 2018). The addition of pollen as a food source for the predatory mite increases its establishment on tomato plants, but it not yet clear whether this translates to control of TRM.

Comparisons of the survival of three predatory mites fed on TRM found that *Typhlodromips swirskii* had the highest net reproductive rate compared to *Typhlodromus athiasae*, and *Paraseiulus talbii*. While TRM was an acceptable food source for *T. swirskii and T. athiasae*, it was not suitable for *P. talbii* (Momen and Abdel-Khalek, 2008). Other studies have found that the following predatory mite species are not successful in controlling TRM: *Euseius concordis*, *Neoseiulus californicus*, *Neoseiulus cucumeris*, *Amplyseius andersoni* (Brodeur et al., 1997, Bouneb, 2014). Agronomists interviewed reported that *T. swirskii* is not very effective, as it cannot cope with the plants' trichomes.

The predatory mite *Tydeus kochi* (Tydeidae) is known to survive well and provides control of TRM populations (Aysan and Kumral, 2018), but is not commercially available. Similarly, *Amblyseius fallacis* is able to survive on TRM with a good reproductive rate (Brodeur et al., 1997). It is commercially available and used to control mites in Canada and USA, but is not registered for use nor available in the EU. The predatory mite can survive between 9 °C to 32 °C, but requires humidity above 50% RH. It is reported as successfully colonising tomato plants and controlling TRM populations. If registered it could be a suitable biocontrol agent for both spider mites and TRM.

### Other predators

*Macrolophus sp.*, are often relied upon to control pests in tomato production. They are not known to have any significant impact on TRM populations. However, it is vital that any control mechanisms developed for TRM are compatible with the use of *Macrolophus sp*. and any other biocontrol agent used in tomato production.

### Bioinsecticides

Naturalis-L or Botanigard (*Beauvaria bassiana*) may be suitable biocontrol agents for controlling TRM populations (Pfaff et al., 2017). *Beauvaria* *bassiana* is known to be effective at controlling other eriophyid mites, such as citrus rust mite (Jaronski, 2014), and has been shown to be highly effective against TRM (Zanolli et al., 2015) at both 125 ml/ha and 250 ml/ha (Ladurner et al., 2007). Naturalis-L should not pose a significant threat to another important biocontrol agent, *Macrolophus pygmaeus* (sold as Mirical by Koppert), as Naturalis-L did not have a significant negative effect on the survival of *Macrolophus caliginosus* (Jacobson and Chandler, 2000). In addition, no significant effects were found for *Phytoseiulus persimilis* and *Aphidius colemani*. Environmental conditions affect *B. bassiana* pathogenicity, and further research is required to confirm *B. bassiana* as a control product and identify the most effective method and conditions for applying *B. bassiana* in tomato for control of TRM.

Growers and agronomists interviewed for this review commented that the effectiveness of *B. bassiana* products are improved when combined with a physically-acting product, e.g. maltodextrin.

The fungal pathogen *Hirsutella thompsonii* infects TRM adults and nymphs, and is used for control in India and Cuba. Natural outbreaks of *H. thompsonii* are extremely devastating to TRM populations (Hamilton and Rajakulendran, 1992).The pathogen is present in the UK (CABI, 2019a), although it is not clear how common it is or which strains occur. Commercial products containing *Hirsutella thompsonii* are available (e.g. MycoHit) but not currently in the UK.

Maltodextrin products (e.g. Majestik) can be effective at reducing TRM populations, and can be combined with sulphur-based products.
One grower reported that TRM outbreaks can be controlled effectively by the use of sulphur sprays and fatty acid sprays (Flipper). Crop scouts check the kill rate after the first spray and 4 – 6 follow up sprays applied every 7 – 8 days, should provide 100 % control. This particular grower never applied conventional acaricides (e.g. abamectin or spiromesifen), only bioinsecticides and sulphur, and achieved consistent control of TRM.
Other agronomists suggested that 3 sprays of sulphur over 10 – 12 days is effective.

Biological products currently available for use in protected tomato crops in the UK are listed in Table 2.

**Table 2: The list of currently available biological products for protected tomato crops in the UK.**

| Example product | Active Substance | Max individual dose | Harvest interval (days) | Total number of applications | Registration expiry in UK |
|---|---|---|---|---|---|
| Botanigard WP | Beauveria bassiana | 0.94 kg/ha | N/A | 5 | 31/10/2022 |
| Flipper | Fatty acids | 16 L / ha | N/A | 5 | 28/02/2023 |
| Majestik | Maltodextrin | 2.5 L / 100 L water | N/A | 20 | 03/08/2021 |
| SB Plant Invigorator | Plant extracts | 200 ml / 100 L water | N/A | N/A | N/A |

**Conventional Insecticides**

Eriophyid mites are generally highly susceptible to conventional acaricides (van Leeuwen et al., 2010). However, because many other pests common in tomato production are effectively controlled by biocontrol agents which would be harmed by conventional pesticides, the use of acaricides for controlling TRM should be a last resort.

Spiromesifen, abamectin, and hexythiazox are highly effective at controlling TRM. Spriomesifen is no longer registered for use in UK tomato production, although it is still available for use in other EU countries, e.g. The Netherlands (Table 3). Hexythiazox is not registered for use in the EU, but is used to control mites in the USA and Australia.

Sulphur-based products are widely used to control mites, including TRM. Microthiol Special was the primary sulphur product regularly used by growers interviewed for this review for controlling outbreaks of TRM. Agronomists and growers reported that several applications might be required to provide adequate control, with regular follow-up monitoring to ensure the spraying was successful. This is a contact acaricide and because TRM are able to shelter in very small spaces, spray operators should ensure they are maximising spray coverage. Using a high spray volume and fine droplets will improve coverage. The use of wetting agents (non-ionic) is permitted and will also improve coverage. Spray operators should consider which parts of the tomato plants are being targeted. The highest density of mites will likely be above the parts of the plant showing visible symptoms.

Acaricides currently available for use in protected tomato crops in the UK are listed in Table 3.

**Table 3: List of acaricide products available for protected tomato crops.**

| Example product | Active Substance | Max individual dose | Harvest interval (days) | Total number of applications | Registration expiry in UK | Comments |
|---|---|---|---|---|---|---|
| Dynamec | Abamectin | 0.05 L / 100 L water | 3 | 3 | 31/10/2022 | |
| Gazelle SG | Acetamiprid | 500 g / ha | 3 | 2 | N/A | Not registered for control of mites, but will kill *A. lycopersici* [1] |
| Floramite 240 SC | Bifenazate | 0.6 L / ha | 1 | 2 | 31/01/2023 | EAMU issued 25/10/2018 until 31/01/2023 for control of two spotted spider mite on tomato [2]. Currently there are no studies on its effect on TRM. |
| Borneo | Etoxazole | 0.035 L /100 L water | 3 | 1 | 31/01/2023 | |
| Envidor | Spirodiclofen | 0.48 L / ha | 3 | 2 | 31/01/2023 | |
| Oberon | Spiromesifen | None | | | No longer available | Effective at killing mites, but no longer registered for use in the UK. Moulting disrupter so not effective once mites reach adult stage. |
| Microthiol Special | Sulphur | 10 g / L | | | 31/12/2021 | Repeated applications may be required. Monitor outbreak to ensure successful spraying. Careful consideration of spray application and spray coverage is essential. |

1. (Lokender et al., 2015). Infestation and management of russet mite, *Aculops lycopersici* in tomato, *Solanum lycopersicum* under protected environment in north-western India.
2. (2999, 2018). Extension of authorisation for a minor use of a plant protection product. Floramite 240 SC. 240 g / l bifenazate

**Current Overseas Control Practices and Opportunities for Application in the UK**

- Spiromesifen (as Oberon) is used elsewhere in the EU and USA to control mites including TRM, but it is no longer registered for use in the UK.
- Hexythiazox is used in the USA and Australia.
- Acequinocyl is under evaluation. Although it is not yet widely used it is available in the USA.
- **Milbemectin** is a bio-pesticide. Available in other EU countries, including Germany and The Netherlands, but not in the UK. It is also used in Australia and USA. Reported as highly effective against all TRM life stages, but has much lower negative effects on *Macrolophus spp.*.
- **Azadiractin** is a bio-pesticide. Known to be effective at controlling TRM and other mites (Zanolli et al., 2015). Used in other EU countries, and Australia, USA, and India.

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