Department for Environment Food & Rural Affairs

# Rapid Pest Risk Analysis (PRA) for:

## *Tomato mottle mosaic virus*

### Date in format: October 2022

# Summary and conclusions of the rapid PRA

Tomato mottle mosaic virus (ToMMV) was first described in tomato crops from Mexico in 2013. Since then, it has been reported from tomato crops in an increasing number of countries around the world, and first reported from the EU in 2015. ToMMV is known to infect solanaceous crops (mainly tomato, peppers, and aubergine). It is closely related to tomato brown rugose fruit virus (ToBRFV) that has been shown to overcome the *Tm-1* and *Tm/Tm-2*$^2$ resistance genes to tobamoviruses. There is also a high amino-acids sequence similarity between ToMMV and tobacco mosaic virus (TMV) and tomato mosaic virus (ToMV) with diagnosis of ToMV and TMV using serological methods having the potential to have be mis-identified and to actually be ToMMV, meaning that ToMMV could be more widespread than initially thought. Currently there have been no reports of damage or symptoms in commercial tomato fruit production. However, there are a couple of disease reports of tomatoes exhibiting ToMMV symptoms at specific production sites in Israel and Mauritius. Data is unavailable on the varieties grown in Israel and it is unknown if they were resistant varieties or not but the report from Mauritius were on varieties that had the *Tm-2*$^2$ resistance gene. The mechanism of this “resistance breaking” is unclear but it is thought that unusually high temperatures in the shadehouses caused the heat sensitive genes that convey resistance to fail. Despite the two isolated incidences of symptom expression, it is thought to be less damaging than ToBFRV. There is some evidence to suggest that many cultivars containing the *Tm2*$^2$ gene may already be resistant or partially resistant against ToMMV and it may be less of a threat than other high risk tobamoviruses such as ToBRFV.

It is the conclusion of this PRA that statutory action is not appropriate for ToMMV. The addition of the *Tm2*$^2$ gene that conveys resistance to ToMV in current commercially available tomato varieties is also very effective against ToMMV. Officially described in 2013 ToMMV has been present in Dutch tomato seed since at least 1977, as well as being misidentified as ToMV in Brazil, Iran, and China in the past. In this time no major outbreaks have been reported, with no evidence of significant economic impacts being found (although the uncertainty around misidentifications as ToMV means it is likely unreported from some areas). The evidence of impacts from Mauritius are thought to have been the result of exceptional circumstances (the unusually hot summer caused the heat sensitive resistance gene to breakdown and allowed for symptom expression). If ToMMV was as damaging as ToBFRV (to which it is often compared) we would expect to have seen more reports of outbreaks and higher impacts than have currently been reported and seen globally.

### Risk of entry

Given the recent UK interceptions of tomato seed batches testing positive for ToMMV, from Vietnam (Ex Japan) and India, (with Vietnam not being recorded in the known distribution of this virus), imported **seeds as a pathway** is rated **very likely** with a **medium confidence**. However, there is still some uncertainty in this score due to the lack of evidence and experimental data on whether ToMMV is seed transmissible to growing plants. However, as a tobamovirus it is highly likely that ToMMV will be transmissible in a small number of plants via virus particles on seed coat as observed with other similar viruses such as ToBRFV. Epidemiological observations of outbreaks in various unrelated regions may also point to seed as pathway.

**Plants for planting** are rated as **moderately likely** with **medium confidence**, mainly due to the known association with plants for planting. ToMMV is more likely to be detected on more established plants for planting due to mitigations that are already in place for other pests and diseases, as symptoms of ToMMV are similar to other high profile tobamoviruses and there is a possibility that symptoms of ToMMV could be detected on plants entering GB. However, as is the case with other tobamoviruses, young plants for planting may be at a developmental stage that means they are not yet showing symptoms or be asymptomatic.

## Risk of establishment

The establishment of ToMMV outdoors in the UK has been rated as **unlikely** with a **high confidence**. Currently in the UK, tomatoes (as well as other solanaceous hosts) are not grown year-round or on a commercial scale outdoors. Tomatoes are, however, a very popular fruit for gardeners and allotment owners and some domestic varieties are grown outdoors. Despite this there is not a strong pathway for ToMMV to “jump” from commercial glasshouses to outdoor grown plants, and if this was to happen, it is expected that instances of this would likely be very localised and on a very small scale.

The establishment of ToMMV under protection has been rated **moderately likely** with a **medium confidence**. As with many other tobamovirus species ToMMV is mechanically transmitted through contact. The handling of infected plants and the movement of infected equipment such as tools, boxes, and clothing between glasshouses in other countries where ToMMV is present have led to rapid spread of the virus in glasshouses (long distance spread is thought to be via seed). Current mitigations in glasshouses to limit the impact of ToBRFV would also help in mitigating the spread/impact of ToMMV, reducing the risk of establishment under glass.

## Economic, environmental, and social impact

Potentially high impacts could be expected if ToMMV has the same levels of damage and yield loss that have been observed in other tobamoviruses such as tomato brown rugose fruit virus (ToBRFV). Symptoms of ToMMV have been observed in Israel in 20% of tomato plants in one greenhouse. In 2019 in Mauritius three separate shade houses had incidences of symptomatic plants in tomato varieties that were resistant (*Tm-2*$^2$ gene baring varieties Eliseo and Policarpo) and one variety that was not (Tropical Rose). In the first instance disease incidence of 10% was observed in the Eliseo variety and then later in the year the varieties Policarpo and Tropical Rose showed disease incidences of 75-80%. It is thought that extremely high temperatures experienced in the shade houses caused a breakdown of resistance. Mixed infections of ToMMV and tobacco mild green mosaic virus (TMGMV) have been reported across several farms in China in aubergine with symptoms observed in 20 to 40% of plants . No data on yield losses were given in these or other studies on outbreaks of ToMMV. ToMMV was first discovered in Mexico in 2013 and has a scattered distribution across the globe, but in all countries where it has been reported, no major losses or damage have been reported. There is also some evidence that some tomato cultivars have resistance to ToMMV due to genes used to convey resistance to tomato mosaic virus (ToMV). The current lack of data on damage, yield loss and resistance in varieties makes this area of the PRA uncertain. **Economic impacts** were rated **medium** with a **low confidence**.

**Environmental impacts** were rated **very small** with a **high confidence** due to the limited host range of ToMMV (mainly solanaceous plants, tomatoes and peppers). In experimental trials, “wild” non-solanaceous hosts often exhibited little to no symptoms of ToMMV. If ToMMV was to infect wild hosts in the UK, it would be very localised with no significant impact to the environment expected. **Social impact** is rated **medium** with a **low confidence** due to the lack of data (to date there have been no reported reductions in tomato fruits or large-scale social impacts in countries it is present in).

## Endangered area

Protected solanaceous crops in UK

## Risk management options

Exclusion in the first instance and then containment at outbreaks if they do occur.

## Key uncertainties and topics that would benefit from further investigation

- Damage/yield losses
- Current resistance in tomato varieties to ToMMV, not all varieties will have been tested against ToMMV, and the symptoms observed in Mauritius show that in certain circumstances (such as extreme heat) ToMMV symptoms can still be expressed in resistant varieties.
- Seed transmission

## Images of the pest

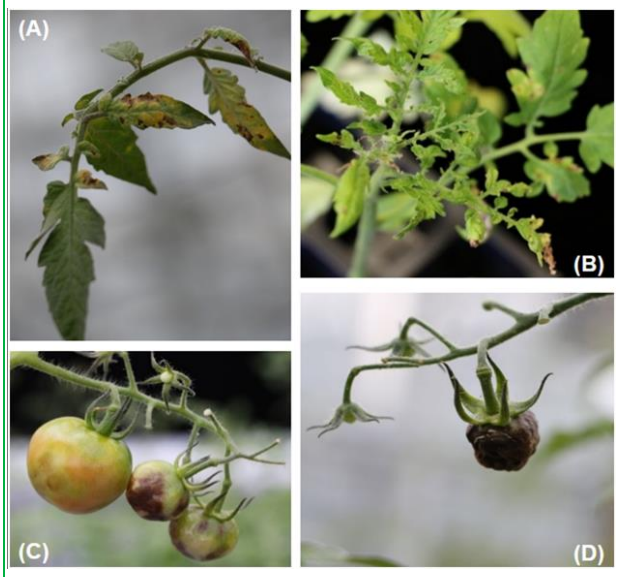



**Figure 1.** Typical symptoms on susceptible cv. B tomato plants infected by ToMMV. **A,** necrotic lesions and chlorosis on leaves; **B**, leaf deformation; **C**, necrotic lesions on fruits; **D**, fruit necrosis. © The American Phytopathological Society, 2017


**Figure 2.** Foliar symptoms of Tomato mottle virus. © EPPO Courtesy: AM Abouzid, JE Polston, E Hiebert (University of Florida, Gainesville and Gulf Coast Research and Education Center, Bradenton, FL (US)).

## Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EPPO) and the PRA scheme (UK or EPPO) to be used.

| | | | | | |
|---|---|---|---|---|---|
| No | ✓ | | | | |
| Yes | | PRA area: UK or EPPO | | PRA scheme: UK or EPPO | |

## Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

*[The text below is a recommendation by the risk analyst which requires approval by PHRG]*

| | | | |
|---|---|---|---|
| Yes Statutory action | | No Statutory action | ✓ |

Due to the areas of uncertainty over elements of ToMMV's biology and impacts to solanaceous crops, further research into seed transmission, yield losses and resistant varieties are proposed in order to help reduce uncertainties. Given that ToMMV is a tobamovirus it is highly likely that it will be "Seed transmitted" as with other tobamoviruses. Transmission via seed is not true seed transmission and does not happen systematically, but via contaminated seed coat that then passes the virus on to the seedling mechanically through small wounds caused when the seed coat splits during germination. This method of transmission doesn't always result in an infected plant and rates of infection can vary and often lead to low numbers of infected plants, these plants however are then highly contagious and can then act as sources of infection for the rest of the crop once established. Eradication of this virus could prove difficult due to the high transmissibility and environmental persistence of this virus. However, the response to ToBRFV and the biosecurity procedures implemented by growers has shown what can be achieved.

Despite being known to science since 2013 there is still little in the way of literature and data on yield losses caused by ToMMV. Given its presence in Dutch seed since 1977 and the misidentifications as ToMV in Brazil, Iran and China in the past, we would expect to have seen more reports of outbreaks and higher impacts than have currently been reported and seen globally, if ToMMV was having major economic impacts where it has been found. With the inclusion of the TM22 gene for resistance against ToMV and subsequently ToMMV within most commercially available varieties, and the lack of reported impacts it is not thought that statutory action is justified.

# Stage 1: Initiation

## 1. What is the name of the pest?

Taxonomic Hierarchy

Family: Virgaviridae - Genus: Tobamovirus - Species: Tomato mottle mosaic virus - Common Name ToMMV.

## 2. What initiated this rapid PRA?

This tobamovirus was first described from Mexico in 2013. Since then, it has been reported from tomato crops in an increasing number of countries around the world. As tomatoes are an important crop in the UK, and in view of the new geographic records, addition to the Risk Register was considered appropriate in early 2017. A review to the RR entry has now been carried out due to the precautionary action being taken on imported seeds testing positive for ToMMV. As a result, this PRA has been initiated to gather more information, help reduce uncertainty for this pest and gather evidence needed to justify further action on interceptions.

## 3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

# Stage 2: Risk Assessment

## 4. What is the pest's status in the plant health legislation, and in the lists of EPPO[1]?

The legislation for Great Britain is The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020[2]. The legislation which applies to Northern Ireland is the EU legislation: 2019/2072 and 2016/2031[3].

The pest is not listed in the GB or EU plant health legislation[2, 3], but it is on the EPPO[1] Alert List.

[1] https://www.eppo.int/ACTIVITIES/quarantine_activities

[2] https://www.legislation.gov.uk/uksi/2020/1527/contents/made

[3] The latest consolidated versions can be accessed via a search on https://eur-lex.europa.eu/

## 5. What is the pest's current geographical distribution?

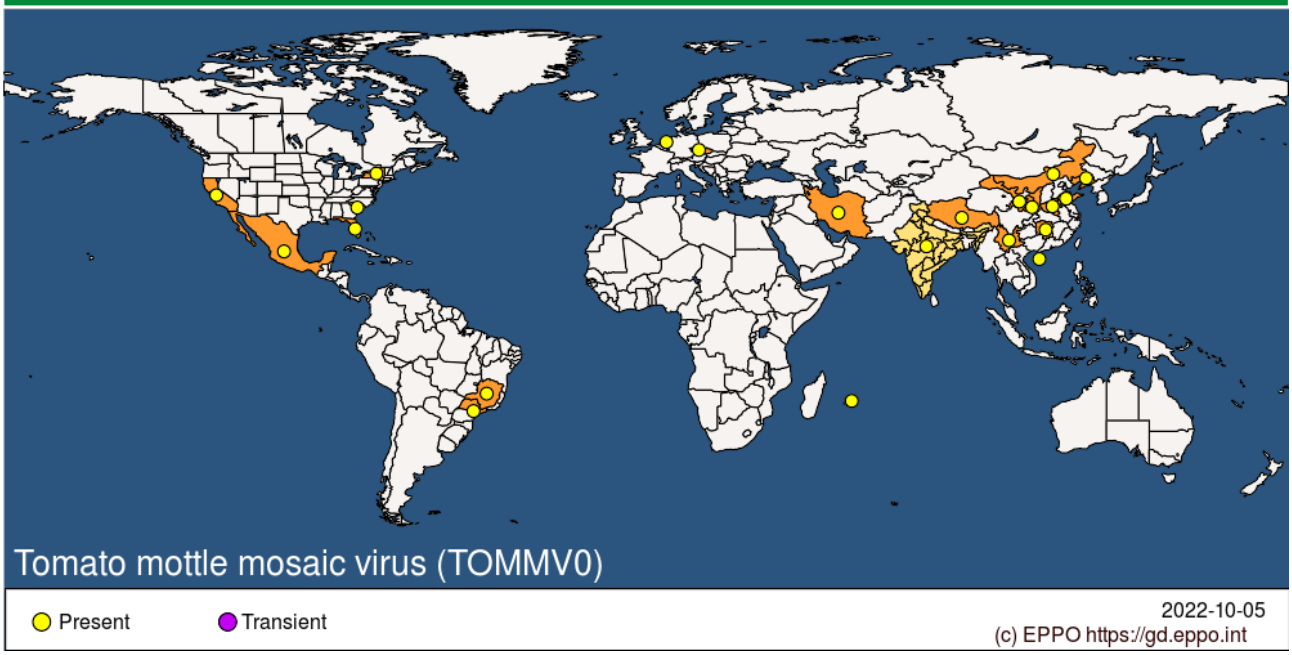
The known distribution is globally scattered. First described from plants in Mexico, ToMMV has since been found in parts of Brazil, China, India, Iran, Israel (though a subsequent survey in the latter failed to detect ToMMV) and the USA (at least Florida and New York State). Additionally, in the UK there have been several interceptions of seed testing positive for ToMMV, one from Vietnam (Ex Japan) and two from India. Vietnam is not recorded in the known distribution of this virus.

Due to the high amino-acid sequence similarity between ToMMV and TMV and ToMV diagnosis of ToMV and TMV using serological methods could be misidentifications of ToMMV, with isolates of ToMV from Brazil, Iran, and China deposited on Genbank now being considered to be ToMMV, meaning that there is the potential for ToMMV to be more widespread in regions where ToMV has been identified in the past. This makes the true distribution of ToMMV more uncertain.

Within Europe, ToMMV has been detected in tomato grown at a Spanish research glasshouse in 2015, and in 2020, ToMMV was identified in three asymptomatic seed crops, two tomato (*Solanum lycopersicum*) one capsicum (*Capsicum annuum*) in Czechia. In 2022 ToMMV was identified for the first time in seeds harvested from plants which were part of a selection programme of candidate varieties grown in The Netherlands. Based on current findings, interceptions in multiple seed lots and earlier findings, it seems likely that ToMMV may be more widespread in Asia and Europe than is currently thought. There have also been recent findings of ToMMV in tomato and *Capsicum* seed collections in the Netherlands that date back to 1977.

| Table : Distribution of *Tomato mottle mosaic virus* | |
|---|---|
| North America: | United States of America (California, Florida, New York, South Carolina), Mexico. |
| Central America: | Absent |
| South America: | Brazil |
| Europe: | Czechia, Netherlands (Spain? Findings at research station) |
| Africa: | Mauritius |
| Asia: | China, India, Iran (?Israel, ?Vietnam*). |
| Oceania: | Absent |

**Current Distribution of *Tomato mottle mosaic virus* (as of October 2022)**



## 6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA Area?

Not known to be present. There are also no known findings of ToMMV in the UK. In 2020 there were four interceptions of seed testing positive for ToMMV, one from Vietnam (Ex Japan) and two from India. Since 2021 there have been 113 interceptions of ToMMV (up to Aug 2022): one of unknown origin, three from India, and one each from China, Japan, and USA.

## 7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

Natural infection has been reported in tomato and peppers (*Capsicum annuum* and *C. frutescens*).

Experimentally, a study in 2017 showed that ToMMV broke resistance of three unspecified tomato cultivars that were resistant to tomato mosaic virus (ToMV). Later studies in 2019 by Nagai *et al*., indicated that the gene *Tm2*$^2$ confers resistance to ToMMV but only in certain varieties that were tested.

Experimental hosts reported to date are:

### Solanaceous hosts

*Nicotiana benthamiana, N. rustica*, *N. tabacum,* and *Solanum nigrum*

### Non-Solanaceous hosts

Arabidopsis thaliana, *Brassica campestris, B. chinensis, B. oleracea, B. pekinensis, Cicer areitinum, Chenopodium quinoa, Datura stramonium, Glebionis coronaria* (asymptomatic), *Gomphrena globose, Petunia* x *hybrida, Physalis alkekengi, P. angulata, P. pubescens, Nicandra physaloides, Raphanus sativus,* and *Verbena officinalis* (asymptomatic).

# 8. Summary of pest biology and/or lifecycle

Tobamoviruses are RNA viruses. The information which follows is applicable to tobamoviruses in general, but there is no reason to believe that ToMMV would differ greatly from other tobamoviruses. Tobamoviruses are very stable outside a host, and therefore can be transmitted mechanically, e.g. by clothes or tools, as well as persisting in soil, growing media and plant debris for long periods (months to years). Several tobamoviruses are known to be seed-borne (infections are carried on the seed coat), and seeds can remain infective for “up to several years”, though the percentage of infected seed is quite low. However, even a small number of infected seedlings can transmit tobamoviruses throughout the crop, especially if seedlings are transplanted, giving the virus the opportunity to spread via wounds in the roots caused by the damage of moving the young plants. ToMMV has been detected on the surface of seeds imported into the UK, however it is unclear if ToMMV on the outside of seed can then be transferred to growing plants as no records were found of any studies into this aspect of its biology. Other Tobamovirus differ as to whether they can be seed-borne or not: some species have high infection rates reported, while for others it has not been demonstrated (A. Fox, Fera Science Ltd., pers. comm.). ToMMV does express both foliar and fruit symptoms. Foliar symptoms include, crinkled or deformed leaves, mosaic, mottling, flecking, chlorosis, and/or necrosis. Symptoms of the fruit include discoloration and rough brown patches or ringspots. Irregular fruit shape and maturation patterns may also occur. Expression of the symptoms is variable between varieties and cultivars, some plants may also be infected but remain asymptomatic.

The Dutch quick scan PRA of ToMMV showed evidence of ToMMV having the ability to break resistance in a small proportion of some tomato cultivars that are resistant to ToMV (have the *Tm2²* gene) (Sui *et al*., 2017 & Nagai *et al*., 2019). However, no yield losses have been reported in commercial crops in the countries that it has been found. Many cultivars are deemed to be resistant against ToMMV as a result of the inclusion of the *Tm2²* gene which conveys resistance to ToMV. It is suspected that ToMMV poses less of a threat than tomato brown rugose fruit virus (ToBRFV), of which there have been many recent outbreaks. There is some evidence from a study in 2019 by Nagai *et al* that varieties/cultivars inoculated with both ToMV and ToMMV with the Tm-2² gene (used to convey resistance to Tobamovirus), showed some resistance to ToMMV but varieties/cultivars that do not, either do not show resistance to ToMMV or at least very little resistance. In the study out of the seven varieties and cultivars of commercially available tomato in Brazil only two ‘Alambra’ and ‘Débora Max’ hybrids showed any uninfected plants. The data from the study proposed the involvement of *Tm-2²* allele in the resistance against ToMMV. The data also reinforces the importance of the studies regarding this virus, since many tomato cultivars and hybrid lines in Brazil as well as worldwide could still be susceptible to ToMMV. The tomato varieties used in the resistance breaking work by Sui *et al* were not specified and simply referred to cultivars ‘B’ ‘E’ and ‘I’. The Dutch quick scan PRA mentions that Dutch breeding companies estimate that nearly 100% of the tomato and pepper cultivars grown in the Netherlands would be resistant to ToMMV (containing the *Tm2²* gene for resistance against ToMV) and as such they do not consider ToMMV as an emerging threat (Information available from

Plantum, Dutch association for the plant reproduction material sector, https://plantum.nl/, September 2020). It would seem that the *Tm-2²* gene can be quite effective against ToMMV, although in some experiments and in the instance in Mauritius, symptomatic plants of cultivars carrying the *Tm-2²* gene have been found, although the mechanisms behind the symptom expression are not fully understood at present.

## 9. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

There are several pathways by which ToMMV could enter the UK. These include import of infected plants for planting, movement of contaminated tools, clothing, etc., or the import of infected seeds. The two main pathways assessed are: the high-volume seeds, on which there is some uncertainty over whether ToMMV is seed-borne, and the lower-volume planting material, which has a known association but uncertainty over the distribution in source propagators in Europe and hence what proportion of plants may be infected. Locally ToMMV can be quickly transmitted mechanically by handling infected plants. As the virus can likely survive on many surfaces (such as tool, clothes etc.) and can easily be spread through a field system or glasshouse. In substrate-less cultures it is thought that the virus can spread via the nutrient solution.

Given the recent interceptions of ToMMV in seed stock, imported seeds as a pathway is rated **very likely** with a **medium confidence**. There is still some uncertainty over direct seed transmission of ToMMV into growing plants. Tobamoviruses tend to accumulate in the reproductive organs of infected plants which leads to virus particles being absorbed into the seed coat. This then has the potential to establish as a primary infection source for “grow-out” plants from the infected seed stock. Typically seeds contaminated with Tobamoviruses show very low virus transmission in grow-out experiments, however there is currently no grow-out data for ToMMV. The more likely route of infection in growing plants from the infected seed coat would be via mechanical infection of damaged roots that occur when transplanting. A low transmission rate to seedlings is observed when tobamoviruses contaminate seeds. However, the large-scale continuous use of seeds and seedlings in commercial production means that even a low percentage of contaminated seeds can cause multiple infections across a site. This can then result in a rapid spread of the virus via mechanical transmission.

Plants for planting are rated as **moderately likely** with a **medium confidence**, mainly due to the known association with plants for planting. ToMMV is more likely to be detected on more established plants for planting due to mitigations that are already in place for other pests and diseases, as symptoms of ToMMV are similar to other high profile tobamoviruses, and there is a possibility that symptoms of ToMMV could be detected on

plants entering GB. However, plant plugs for planting may be at a developmental stage that means they are not yet showing symptoms.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Imported tomato seed* | Very unlikely | ☐ | Unlikely | ☐ | Moderately likely | ☐ | Likely | ☐ | Very likely ☑ |
| *Confidence* | High Confidence | ☐ | Medium Confidence | ☑ | Low Confidence | ☐ | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Tomato plants for planting* | Very unlikely | ☐ | Unlikely | ☐ | Moderately likely | ☑ | Likely | ☐ | Very likely ☐ |
| *Confidence* | High Confidence | ☐ | Medium Confidence | ☑ | Low Confidence | ☐ | | | |

## 10. If the pest needs a vector, is it present in the UK/PRA area?

Currently no insect vectors are known. However, there is preliminary evidence that another recently described tobamovirus, ToBFRV, can be transmitted by bumblebees.

## 11. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

The establishment of ToMMV outdoors in the UK has been rated as **unlikely** with a **high confidence**. Currently in the UK, tomato crops are not grown on a commercial scale outdoors. Tomatoes are, however, a very popular fruit for gardeners and allotment owners and some varieties are grown outdoors. Despite this there is not a strong pathway for ToMMV to “jump” from commercial glasshouses to outdoor grown plants, and if this did happen instances of this would likely be very localised and at a very small scale.

The establishment of ToMMV under protection has been rated **moderately likely** with a **medium confidence**. As with many other tobamovirus species, ToMMV is easily transmitted through contact. This can be with contaminated material such as tools or clothing as well as plant to plant contact and through infected soil. The handling of infected plants and the movement of infected equipment between glasshouses in other countries where ToMMV is present has led to rapid spread of the virus in glasshouses. The current extensive mitigations in place to limit the impact of ToBRFV in commercial glasshouses would also be effective in mitigating against the spread and impact of ToMMV

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|---|---|---|---|---|---|---|---|---|---|---|
| *Outdoors* | Very unlikely | ☐ | Unlikely | ☑ | Moderately likely | ☐ | Likely | ☐ | Very likely | ☐ |
| *Confidence* | High Confidence | ☑ | Medium Confidence | ☐ | Low Confidence | ☐ | | | | |
| *Under Protection* | Very unlikely | ☐ | Unlikely | ☐ | Moderately likely | ☑ | Likely | ☐ | Very likely | ☐ |
| *Confidence* | High Confidence | ☐ | Medium Confidence | ☑ | Low Confidence | ☐ | | | | |

## 12. How quickly could the pest spread in the UK/PRA area?

Natural spread of ToMMV is expected to be minimal and is scored **very slowly** with a **high confidence**. Currently the spread of ToMMV globally and locally appears to be the result of human activities, such as handling infected plants or the use of unclean equipment between sites. The virus does not disperse far naturally.

Spread via trade is rated as **quickly** with a **high confidence**. ToMMV is highly transmissible and easily spread through contact or via unsanitised equipment moved between sites. Tobamoviruses are also known for their stability and can survive for long periods of time on surfaces and equipment and can persist in soil / growing media. This environmental stability can lead to re-infections as the virus can be transferred from surfaces to infect plants. It is possible for contamination to occur in propagation, either through the seed, or through mechanical / physical contact and the movement of infected planting material itself is likely to facilitate spread.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Natural Spread* | Very slowly | ☑ | Slowly | ☐ | Moderate pace | ☐ | Quickly | ☐ | Very quickly | ☐ |
| *Confidence* | High Confidence | ☑ | Medium Confidence | ☐ | Low Confidence | ☐ | | | | |
| *With trade* | Very slowly | ☐ | Slowly | ☐ | Moderate pace | ☐ | Quickly | ☑ | Very quickly | ☐ |
| *Confidence* | High Confidence | ☑ | Medium Confidence | ☐ | Low Confidence | ☐ | | | | |

## 13. What is the pest's economic, environmental, and social impact within its existing distribution?

At present there is very little qualitative or quantifiable data available for the impacts of ToMMV. Literature on the subject mention that ToMMV poses a major threat for tomato crops but there is still almost no data on impacts, other than lists of symptoms in various papers reporting ToMMV from a new country.

Tomato leaves show mosaic symptoms on their leaves which are also deformed, may have systematic crinkling and some may grow downwards. Necrosis has also been observed. This is reported to reduce yield, though no quantitative data are available. No fruit symptoms are detailed in the available literature. Some tomato cultivar/virus strain combinations appear to produce stunting symptoms. Experimentally inoculated tomato seedlings show tissue necrosis on their upper leaves.

Natural infection of pepper in China were shown to have similar symptoms to those reported in tomato, and the infection rate was stated to be 3.6%.

Another disease report for a mixed infection of ToMMV and TMGMV from China mentioned symptoms were observed in 20 to 40% of aubergine plants (*Solanum melongena* L.) across several farms. The two reports did not have any data on yield losses.

In all countries where it has been recorded, no major losses or damage have been reported. The current lack of data on damage, yield loss and resistant varieties makes economic impacts hard to assess. Most reports, however, estimate losses similar to those caused by other Tobamoviruses (such as ToBRFV and ToMV) with estimated losses up to 25% in infected non-resistant varieties. A report form 2016 (Turina *et al*., 2016) stated that at a glasshouse in Israel 20% of tomato plants exhibited severe symptoms and reduced production due to ToMMV. It is currently unknown if this was in a resistant variety or not. In 2019 in Mauritius three separate shade houses had incidences of symptomatic plants in tomato varieties that were resistant (*Tm-2²* gene baring varieties Eliseo and Policarpo) and one variety that was not (Tropical Rose). In the first instance disease incidence of 10% was observed in the Eliseo variety and then later in the year the varieties Policarpo and Tropical Rose showed disease incidences of 75-80%. It is thought that extremely high temperatures experienced in that summer in the shade houses (temperatures were estimated to have reached between 25-30°C) had reduced the effectiveness of the temperature sensitive *Tm-2²* gene that is used to convey resistance to ToMV/ToMMV. It would seem that the *Tm-2²* gene seems to be quite effective against ToMMV, although in some experiments and in two shade houses in Mauritius, symptomatic plants of cultivars carrying the *Tm-2²* gene have been found.

Due to the lack of data on impacts of ToMMV, data for ToBRFV is often used as a proxy indicator for the types of losses that could be expected for ToMMV. While closely related there is currently no evidence that the levels of damage/impacts for ToBRFV would be the same for ToMMV, and the lack of data on the subject could indicate that impacts are not as high as with ToBRFV. If ToMMV was to have similar impacts as ToBRFV then infected plants in a crop could be expected to be as high as 100% but with infection rates of 10-15% more common. In outbreaks with 100% infection, yield losses between 25 and 70% were reported for ToBRFV. The losses reported are largely due to the unmarketability of the fruit and the loss of production period through plant death and the time cost involved through the removal of infected crops and cleaning of glasshouses etc.

As stated above there is very little data on yield losses or damage caused, despite its presence across multiple sites around the globe. As mentioned in section 8 there is some evidence that cultivars with the *Tm2²* gene resistant to ToMV may also be resistant to ToMMV, however there is also evidence that ToMMV can break resistance in a small proportion of certain cultivars resistant to ToMV. Overall, the *Tm-2²* gene appears to be quite effective against ToMMV, although the instance in Mauritius shows that symptomatic plants of cultivars carrying the *Tm-2²* gene have been found.

Given the rapid spread of ToBRFV in glasshouses in the EU and the fact that tobamoviruses are known to spread rapidly and cause high levels of damage/yield loss to susceptible crops, the lack of evidence of losses for ToMMV may suggest that tomato crops in Europe are not highly susceptible or could even be resistant against ToMMV. But without any data on resistance varieties of ToMMV and crop damage/losses this area of the PRA remains uncertain and thus with the evidence of some damage in some instances impact is rated **medium** with **low confidence**.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Impacts* | Very small | ☐ | Small | ☐ | Medium | ☑ | Large | ☐ | Very large ☐ |
| *Confidence* | High Confidence | ☐ | Medium Confidence | ☐ | Low Confidence | ☑ | | | |

## 14. What is the pest's potential to cause economic, environmental and social impacts in the UK/PRA area?

If the impacts of ToMMV do turn out to be similar to other related tobamoviruses then we could expect the impacts to be just as high (as discussed in section 13). Currently these uncertainties are reflected in the score. At present (October 2022) there is no evidence of large-scale damage or yield losses in any of the countries where ToMMV is found. It is unknown as to why this is. There is the possibility that a certain amount of resistance to ToMMV is already present in the commercially grown varieties of tomato. The Dutch quick scan PRA did state that Dutch breeding companies consider that nearly 100% of the tomato and pepper cultivars grown in the Netherlands would be resistant to ToMMV. Many of the commercial tomato varieties grown in the UK are from Dutch seed houses (Rijk Zwaan, De Ruiter) as well as some French suppliers (Gautier) (Marcus Lazenby, PHSI., pers. comm). A check of the seed catalogues of these seed houses shows that tomato varieties available have "high resistance" to ToMV which could convey resistance to ToMMV. The lack of available information on the impacts and resistance of varieties to ToMMV means that the economic impact has been rated **medium**, in line with impacts elsewhere, but with a **low confidence**.

Environmental impacts are expected to be **very small**, with **high confidence**. ToMMV has a limited host range naturally (solanaceous plants, tomatoes and peppers). In experimental trials, "wild" non-solanaceous hosts often exhibited little to no symptoms of ToMMV. Spread of ToMMV outdoors is considered to be slow with major movements of ToMMV in regions mainly due to human activities. If ToMMV was to infect wild hosts in the

UK, it would be very localised. No significant impact to the environment is expected. However, some susceptible garden or allotment host plants may be impacted if infected by ToMMV.

Social impacts could be expected as a result of ToMMV. Tomatoes are a popular fruit and widely used and consumed throughout the UK. A disease that could lead to lower quality or shortages of fruits is likely to have an impact on businesses and consumers. There is also likely to be media interest especially if there is reduced availability of tomatoes in the UK. Social impact is rated **medium** with a **low confidence** due to lack of data (to date there have been no reported reductions in tomato fruits or large-scale social impacts in countries it is present in).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Economic Impacts* | Very small | ☐ | Small | ☐ | Medium | ☑ | Large | ☐ | Very large | ☐ |
| *Confidence* | High Confidence | ☐ | Medium Confidence | ☐ | Low Confidence | ☑ | | | | |
| *Environ - mental Impacts* | Very small | ☑ | Small | ☐ | Medium | ☐ | Large | ☐ | Very large | ☐ |
| *Confidence* | High Confidence | ☑ | Medium Confidence | ☐ | Low Confidence | ☐ | | | | |
| *Social Impacts* | Very small | ☐ | Small | ☐ | Medium | ☑ | Large | ☐ | Very large | ☐ |
| *Confidence* | High Confidence | ☐ | Medium Confidence | ☐ | Low Confidence | ☑ | | | | |

## 15. What is the pest's potential as a vector of plant pathogens?

ToMMV is a plant pathogen with no capacity to act as a vector of other pathogens.

## 16. What is the area endangered by the pest?

Protected cultivation of solanaceous crops especially tomatoes and bell peppers.

# Stage 3: Pest Risk Management

## 17. What are the risk management options for the UK/PRA area?

### Exclusion

Currently ToMMV is not known to be found in the UK, so exclusion of this pest from the PRA area is still an option. Typical control measures used for other Tobamoviruses could be used here, such as: sampling seed at the point of entry and holding consignments until the results are available, the use of virus free seed and planting/propagating material, as well as production free site declarations. Other tobamoviruses such as ToBRFV are listed as quarantine pests in GB, so ToMMV could also be considered for listing providing it meets requirements.

If ToMMV meets the requirements of a QP, measures similar to those that are in place for ToBRFV could be an option. The following measures in place for ToBRFV could be applied to ToMMV:

- Official statements that seed and varieties imported into GB are known to be resistant to ToBRFV
- Official statements that the mother plants of seeds have been produced in a production site where ToBRFV is known not to occur on the basis of official inspections carried out at the appropriate time to detect that pest, and that the seeds or their mother plants have undergone official sampling and testing for ToBRFV and have been found, according to those tests, to be free from that pest.
- Official statements that any plants are derived from seeds which have undergone sampling and testing for ToBRFV and are shown to be free from that pest.

For full list of measures see phytosanitary conditions regulation Annex 7 and 8 Part B (found here: https://www.legislation.gov.uk/uksi/2020/1527/schedule/7/made)

### Eradication and containment

Eradication is possible, recent experience with ToBFRV has shown what can be achieved. By the time symptoms have been noticed in a glasshouse infection has already occurred with the possibility of spread to other glasshouses on a site via mechanical transmission on clothing, physical contact or tools. As a result, when the virus is first found in a glasshouse it is important that restrictions are put in place on movement of infected seed and plants, as well as tracing the movements of any potentially infected seed or plants. Phytosanitary measures that have been used against ToBRFV are proposed. These measures include:

- Removal of all the infected crop and associated plant debris. This can be disposed of by incineration, deep burial or another approved method.

- Destruction (or recycling for non-horticultural use if applicable) of all remaining material e.g., string, plastic flooring, and growing media, once the infected crop has been removed.

- All areas of the glasshouse (aside from soil) should subsequently be cleaned with water and detergent to remove traces of organic matter, and then disinfected.

- Measures should be taken to prevent the germination of self-sown tomato and pepper seeds prior to the introduction of a new crop e.g., using herbicide or salt treatment on areas where self-sown plants are likely to occur.

- Water is also a potential route of transmission. As a precaution, the irrigation system should be decontaminated and cleaned out at the end of the season. Water sources should be free from the virus, and, if possible, water should not be mixed between infected and non-infected lots.

- Before the introduction of a new host crop, there should be a host crop-free period. During this period. If the plants are grown in soil, a longer crop-free period may be required if soil cannot be removed. Alternatively, the removal of soil (if possible) could be used. Growers may opt to use a break crop, such as cucumber. After the new host crop has been planted, regular monitoring should be carried out to ensure that self-sown seedlings or potential host weeds are not growing in or in close proximity to the glasshouse. Early removal is important, as self-sown seedlings from the infected crop can transfer ToBRFV to the next crop.

- An official inspection at production sites should be conducted in spring, with a possible follow up inspection carried out later in the season if no symptoms are seen, to check the following crop for symptoms of ToBRFV. The optimum time for inspection at propagation sites may vary. Samples will also be taken of asymptomatic host material.

When contaminated plants are found phytosanitary measures should be taken as swiftly as possible. ToMMV as with other tobamoviruses can spread rapidly within a glasshouse via human contact. The virus can also persist on surfaces for long periods of time. Tools, clothing and equipment from the infested site should not be moved off site unless it has been thoroughly cleaned and disinfected. Good hygiene practices should be followed at all times both prophylactically and following suspicion/confirmation of the virThe GB ToBRFV

contingency plan (https://planthealthportal.defra.gov.uk/assets/uploads/Tomato-brown-rugose-fruit-virus-contingency-plan-v7.pdf) outlines the following practices:

- Training staff to recognise symptoms of ToBRFV and to use good hygiene practices
- Monitoring of the crop for symptoms of ToBRFV
- Assigning equipment and workers to particular sections of the glasshouse, and ensuring workers pass through a hygiene lock upon entry and exit of each section
- Maintaining the working direction. If human-assisted spread of a pathogen occurs, it will occur in the direction that the human is working. Working in the same direction reduces the extent of the spread and allows measures to be carried out in a more concentrated way.
- Washing and disinfecting equipment. This should be done between every row and ideally between individual plants, but at least between crops.
- Using disposable gloves, which should be replaced regularly
- Using disposable clothing, which should only be used when entering the glasshouse or section of the glasshouse and removed upon leaving the glasshouse or section and not reused
- Prohibiting the consumption of fresh tomato and pepper on site e.g., in sandwiches
- Prohibiting the introduction of ornamental plants on site e.g., Petunia, which is an experimental host
- Restricting the introduction of items, such as jewellery, watches and phones into the glasshouse (Netherland's hygiene protocol, 2019). If a phone must be brought into the glasshouse, it must be placed in a sealed plastic disinfected cover.
- Double bagging samples taken and disinfecting the outer packaging.
- Cleaning and disinfection of the glasshouse following the removal of plants.
- Volunteer plants and weeds, such as *Chenopodium murale* and *Solanum nigrum*, may act as reservoirs for ToBRFV. Controlling these plants within and around glasshouses reduces the chance of the crop becoming infected and reduces the risk of survival and persistence of the pest in the event of an outbreak.
- Any fallen fruit and other debris that may harbour the virus should also be regularly removed and destroyed

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This publication is available via the UK Plant Health Information portal https://planthealthportal.defra.gov.uk/

This PRA has been undertaken following IPPC International Standards for Phytosanitary Measures (ISPMs 2 and 11) and it provides technical evidence relating to the risk assessment and risk management of this pest.

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