The Food and Environment Research Agency

Pest Risk Analysis for

Tobacco mild green mosaic virus

STAGE 1: PRA INITIATION

1. What is the name of the pest?
Tobacco mild green mosaic virus (TMGMV) (see Brunt *et al*., 1996 for the description).

Synonyms:
Mild dark-green tobacco mosaic virus
Para-tobacco mosaic virus
Mild strain of tobacco mosaic virus
South Carolina mild mottling strain of tobacco mosaic virus
Strains U2 and U5 of tobacco mosaic virus
Green-tomato atypical mosaic virus

Taxonomic position:
Virus
Family: *Virgaviridae*
Genus: Tobamovirus

Special notes on nomenclature or taxonomy:
None.

2. What is the pest's status in the EC Plant Health Directive (Council Directive 2000/29/EC[1]) (Anon., 2000)
Not listed.

3. What is the recommended quarantine status of the pest in the lists of EPPO[2]?
Not recommended for consideration for regulation as a quarantine pest by EPPO and not on the EPPO Alert List.

4. What is the reason for the PRA?
There have been two confirmed cases of *Tobacco mild green mosaic virus* at UK nurseries on impatiens (in 2007) and osteospermum (in 2008) plants from the EU. Both outbreaks were eradicated, but there is concern that infected ornamental plants may act as a reservoir for infection of *Capsicum* and possibly tomato and this initiated a rapid assessment. Subsequent to presentation of the draft rapid assessment at the UK Plant Health Risk Management Workstream in January 2012 it was agreed that the document be developed into a full UK PRA.

5. What is the PRA area?

[1] http://europa.eu.int/eur-lex/en/consleg/pdf/2000/en_2000L0029_do_001.pdf
[2] http://www.eppo.org/QUARANTINE/quarantine.htm

UK [✓] EU[3] [ ] EPPO[4] [ ]

STAGE 2: PEST RISK ASSESSMENT

6. What is the pest's present geographical distribution?

The full list of natural hosts in Table 1 below includes the geographic location of the findings and supporting references. An outline is give below:

TMGMV was first reported in the Canary Islands in the wild host *Nicotiana glauca* (McKinney, 1929) and it is thought to be widespread within this host wherever it is distributed, including North America (USA), Australia, and in the European and African countries of France (including Corsica), Madeira, the Canary Islands and Tunisia. In Germany TMGMV is common in field tobacco (*Nicotiana tabacum*). There have been reported findings in other hosts on a range of continents in Korea, Taiwan, Venezuela, southern France, Italy, Israel, Tunisia, Panama, and recently in Iran on tomato (Alishiri, 2011) as well as on more hosts in the USA. The UK has found the virus in UK nurseries twice on material imported from Belgium and Denmark (Skelton, 2010), but it has been eradicated. There are no records of the virus in these countries.

Geographic locations:

North America:	USA
Central America:	Panama
South America:	Venezuela
Caribbean:	Not reported
Europe:	France (including Corsica), Madeira, Germany, Italy
Africa:	Canary Islands, Tunisia
Middle East:	Israel
Asia:	Korea, Taiwan, Iran
Oceania:	Australia

7. Is the pest established or transient[5], in the PRA area? *(Include information on interceptions and outbreaks here).*

No – the virus is not considered to be established or transient in the UK but no official surveys have been undertaken here to date.

There have been two confirmed cases of TMGMV in the UK. The first case in 2007, was in impatiens which had been imported from Belgium. The second case in 2008, was in osteospermum plants imported from Denmark. There are no known reports of the pest in either exporting country. TMGMV has since been eradicated from the UK.

8. Is there any reason to suspect that the pest is already established in the PRA area?

See 7. Outbreaks have occurred but are considered to be eradicated. No official surveys have been undertaken to determine the status of the virus to date.

9. What are the pest's host plants? List natural and experimental hosts.

TMGMV has a wide host range infecting several different families. The full list of natural and experimental hosts is given in Table 1 and Table 2 below along with the supporting references.

[3] If the PRA area is the EU then it excludes locations such as the French DOMS, Spanish Canary Isles and Portuguese Azores and Madeira.

[4] EPPO = The whole EPPO region concentrating on the European and Mediterranean area, i.e. EPPO west of the Ural Mountains.

[5] Transience: presence of a pest that is not expected to lead to establishment (ISPM No., FAO, Rome)

The most economically important known host plants of TMGMV in the UK are *Capsicum* spp. (*C. annuum* and *C. chinense*) and tomato (*Solanum lycopersicum)*. There have been several reported cases of natural infection of *Capsicum* spp., both glasshouse and field crops, outside of Europe (Korea, Venezuela, Taiwan, Tunisia and Panama). Reported symptoms are generally quite mild, but there is very little information available on the effect of the virus on the fruit. Although there is conflicting evidence of whether tomato is a host, there has recently been a first report of TMGMV infecting a tomato crop in Iran (Alishiri, 2011). It is thought to be very rare for tomato to be a host of TMGMV because of the resistance gene (Tm) which is responsible for tomato basal defence to tobamoviruses like TMGMV (F Rakhshandehroo, Islamic Azad University, Iran, personal communication, 2011), however there is no information regarding how widespread this resistance gene is in tomato varieties.

Natural infection has been reported in a variety of ornamentals in a range of families including *Petunia* spp., *Calibrachoa* spp*., Eryngium aquaticum, Eryngium planum,* cultivated Gesneriads, *Impatiens* spp., *Nicotiana glauca* (tree tobacco) *Osteospermum* spp., *Rhoeo spathacea*, *Torenia fournieri* and *Tabernaemontana divaricata.*

The other important natural host is *N. tabacum* (field tobacco); this is not cultivated in the UK however.

Table 1*.* Natural hosts of *Tobacco mild green mosaic virus.*

Host		**Family**	**Symptom or location of detection**	**Location**	**Date sample taken**	**Reference**
Scientific name	Common name					
Calibrachoa spp.	Calibrachoa	Solanaceae	Symptoms – chlorotic yellow spots, rings, vein banding and mosaic? Detection – foliage?	Israel	2006	Zeidan *et al*., 2008
			Symptoms – reduced growth, general chlorosis and blistering of foliage. Detection – foliage	USA	2007	Sabanadzovic *et al*., 2009
Capsicum annuum	Pepper	Solanaceae	Mild mosaic on young leaves and chlorotic ringspots on intermediate ones.	Italy	1970	Wetter *et al*., 1986
			Symptoms – mild mosaic. Detection – foliage?	Korea	2001/2	Choi *et al*., 2002
			Symptoms - mild chlorosis and necrotic lesions. Detection - foliage	Taiwan	2003	Li *et al*., 2004
			Symptoms - leaf deformation, mild green	Tunisia	2007/8	Font *et al*., 2009

			and chlorotic mosaic. Detection - foliage			
			Symptoms - bubbling, curling, green-yellow mosaic, deformation, ringspot and necrosis of leaves and distortion of fruit. (Mixed infection with CMV, PMMoV and PVY). Detection - foliage	Panama	2008	Herrera-Vasquez *et al*., 2008
			Severe necrotic mosaic, plants often killed	?	?	ICTVd descriptions
Capsicum chinense	'Aji dulce' or 'Habanero chili (chilli pepper)	Solanaceae	Symptoms - curling and bubbling of leaves. Detection - foliage and seed	Venezuela	2003	Cordoba *et al*., 2006
Eryngium aquaticum	-	Apiaceae / Umbelliferae	Systemic yellow flecking	?	?	ICTVd descriptions
Eryngium planum	-	Apiaceae / Umbelliferae	Systemic yellow flecking	?	?	ICTVd descriptions
Gesneriads (cultivated)	-	Gesneriaceae	Mild symptoms	USA	?	Zettler *et al*., 1983
Impatiens spp.	Impatiens	Balsaminaceae	Symptoms - stunting, distorted leaves, necrotic lesions and paler flower colour. Detection - foliage	UK	2007	Skelton *et al*., 2010
Nicotiana glauca	Tree tobacco	Solanaceae	Bright yellow mosaic, mottling, ringspots and cupping, stunting	Canary Islands	1929	McKinney, 1929 Wetter, 1984
			Bright yellow mosaic	Australia	?	Randles *et al*., 1981
			?	Madeira	?	Wetter, 1984
			?	Tunisia	?	Wetter, 1984
			?	Corsica, France	?	Wetter, 1984
			Yellow mosaic & aucaba mottle (light and dark green areas)	USA	?	Bald *et al*, 1960
			?	USA	?	Bodaghi *et al*., 2004
Nicotiana tabacum	Field tobacco	Solanaceae	Mild green mosaic with oak leaf patterns	Germany		Wetter, 1984b Association of Applied Biologists, Descriptions of Plant Viruses
Osteospermum spp.	Osteospermum	Asteraceae/ Compositae	Symptoms – chlorotic spots and rings on the leaves. Detection - foliage	UK	2008	Skelton *et al*., 2010
Petunia spp.	Petunia	Solanaceae	Symptoms – chlorotic yellow spots,	Israel	2006	Zeidan et al., 2008

			rings, vein banding and mosaic? Detection – foliage?			
Rhoeo spathacea	-	Commelinaceae	Mosaic	USA	?	Baker *et al*., 1988
Solanum lycopersicum	Tomato	Solanaceae	Symptoms – interveinal chlorosis, distortion and necrosis of leaves and stem. Affected plants dry up in final stages. Detection – foliage?	Iran	2009/10	Alishiri, 2011
Petunia integrifolia	Trailing petunia/Petunia Surfinia	Solanaceae	Symptoms – yellow mosaic and distortion of the leaves with vein necrosis in some samples. Deformed flowers and light colour break of the petals. Detection - foliage	France	2003/4	Parrella *et al*., 2006
Tabernaemontana divaricata	-	Apocynaceae	?	Israel	?	Zeidan *et al*., 2008
Torenia fournieri	-	Scrophulariaceae	Symptoms – chlorotic yellow spots, rings, vein banding and mosaic? Detection – foliage?	Israel	2006	Zeidan *et al*., 2008

Footnote to Table 1: ? = unknown

Under experimental conditions several species in a range of families are susceptible to TMGMV, these include members of the Chenopodiaceae, Labiatae, Solanaceae and Umbelliferae and others.

Table 2. Results of inoculation experiments with *Tobacco mild green mosaic virus*.

Isolate source	**Experimental host**	**Common name**	**Family of experimental host**	**Plant material**	**Inoculation method**	**Resulting symptom**	**Reference**
Calibrachoa	*Nicotiana benthamiana* *Nicotiana tabacum* cv. Xanthi & Turkish *Nicotiana rustica* *Nicotiana clevelandii* *Nicotiana glutinosa* *Capsicum annum* cv. Sweet banana	Pepper	Solanaceae	Plants	Sap inoculation	Systemic mosaic, mottling & necrosis	Sabanadzovic *et al*., 2009

Capsicum	*Chenopodium amaranticolor* *Gomphrena globosa* *Physalis floridana* *Nicotiana occidentalis* *Nicotiana rustica* *Nicotiana tabacum* cv. Samsun		Amaranthaceae - Chenopodiaceae Amaranthaceae Solanaceae Solanaceae Solanaceae Solanaceae	Plants	Sap inoculation	Necrotic spots No reaction (tested negative) Chlorotic spots & mosaic Mosaic Necrotic spots Necrotic spots	Choi *et al*., 2002
Capsicum	*Capsicum* *Solanum lycopersicum* cv. Marmande	Pepper Tomato	Solanaceae Solanaceae	Plants	Sap inoculation	Mild chlorosis Asymptomatic (tested negative)	Font *et al*., 2009
Capsicum	*Capsicum* *Chenopodium amaranticolor* *Chenopodium quinoa* *Nicotiana benthamiana* *Nicotiana debneyi*	Pepper	Solanaceae Amaranthaceae - Chenopodiaceae Amaranthaceae - Chenopodiaceae Solanaceae Solanaceae	Plants	Sap inoculation	Mild chlorosis developing into necrosis and then leaf drop Local chlorotic lesions Local chlorotic lesions Systemic mosaic Systemic mosaic	Li *et al*., 2004
Capsicum	*Capsicum annuum* *Eryngium planum* *Solanum lycopersicum*	Pepper Tomato	Solanaceae Apiaceae / Umbelliferae Solanaceae	Plants	Sap inoculation	Systemic infection, local necrotic lesions followed by leaf drop, some plants developed systemic necrosis Systemic infection No infection	Wetter *et al*.,1986
Capsicum	*Capsicum frutescens* *Chenopodium quinoa* *Datura stramonium* *Eryngium planum* *Solanum lycopersicum cv Hoffmann's Rendita* *Nicotiana clevelandii*	Chili pepper Tomato	Solanaceae Amaranthaceae - Chenopodiaceae Solanaceae Apiaceae / Umbelliferae Solanaceae Solanaceae	Plants	Sap inoculation	Necrotic local lesions Chlorotic local lesions Necrotic local lesions Mosaic / mottle, systemic infection No infection Mosaic / mottle, systemic infection	Wetter, *et al.,* 1987

	Nicotiana debneyi		Solanaceae			Chlorotic local lesions, systemic necrotic infection	
	Nicotiana glauca	Tree tobacco	Solanaceae			Mosaic / mottle, systemic infection	
	Nicotiana glutinosa		Solanaceae			Necrotic local lesions	
	Nicotiana sylvestris		Solanaceae			Necrotic local lesions	
	Nicotiana tabacum cv. Samsun		Solanaceae			Mosaic / mottle, systemic infection	
	Nicotiana tabacum cv. White Burley		Solanaceae			Necrotic local lesions	
	Nicotiana tabacum cv. Xanthi		Solanaceae			Necrotic local lesions	
	Petunia hybida	Petunia	Solanaceae			Necrotic local lesions	
	Capsicum annuum (various varieties)	Pepper	Solanaceae			Necrotic local lesions, systemic necrotic infection, mosaic or mottle, chlorotic local lesions, lethal infection	
Impatiens	*Chenopodium quinoa*		Amaranthaceae - Chenopodiaceae	Plants	Sap inoculation	Local chlorotic lesions	Skelton *et al*., 2010
	Nicotiana benthamiana		Solanaceae			Systemic necrosis	
	Nicotiana hesperis		Solanaceae			Systemic necrosis	
	Nicotiana occidentalis		Solanaceae			Systemic necrosis	
Nicotiana glauca	*Solanum lycopersicum cv. Marmande*	Tomato	Solanaceae	Plants	Sap inoculation	No reaction (tested negative)	Wetter, 1984
Osteospermum	*Chenopodium quinoa*		Amaranthaceae - Chenopodiaceae	Plants	Sap inoculation	Local chlorotic lesions	Skelton *et al*., 2010
	Nicotiana benthamiana		Solanaceae			Systemic necrosis	
	Nicotiana hesperis		Solanaceae			Systemic necrosis	
	Nicotiana occidentalis		Solanaceae			Systemic necrosis	
Rhoeo spathacea	*Commelina communis*	Asiatic dayflower	Commelinaceae	Plants	Sap inoculation	Systemic infection	Baker *et al*., 1988
	Zebrina pendula		Commelinaceae			Systemic infection	

Tomato	*Nicotiana tabacum* cv. Samsun	Tobacco	Solanaceae	Plants	Sap inoculation	Systemic mosaic and necrosis in young leaves	Alishiri *et al*., 2011
Unknown	*Capsicum annuum* *Datura stramonium* *Eryngium planum* *Solanum lycopersicum* *Nicotiana glauca* *Nicotiana glutinosa* *Nicotiana sylvestris* *Nicotiana tabacum cv. Samsun* *Nicotiana tabacum cv. White Burley*	Pepper Tomato Tree tobacco Tobacco Tobacco	Solanaceae Solanaceae Apiaceae / Umbelliferae Solanaceae Solanaceae Solanaceae Solanaceae Solanaceae	Plants	Sap inoculation	Systemic mosaic Local lesions Systemic mosaic No infection Systemic mosaic Local lesions Local lesions Systemic mosaic Local lesions	Wetter, 1984
Unknown	*Nicotiana glutinosa* *Nicotiana sylvestris* *Nicotiana tabacum cvs Xanthi, White Burley*		Solanaceae	Plants	Sap inoculation	Systemic yellow mosaic, ringspots	ICTVd descriptions
Unknown	*Ocimum basilicum*	Basil	Lamiaceae/ Labiatae	Plants	Sap inoculation	?	ICTVd descriptions
Unknown	*Nicotiana glutinosa* *Nicotiana sylvestris* *Nicotiana tabacum cvs Xanthi, White Burley*		Solanaceae	Plants	Sap inoculation	Small necrotic local lesions, no systemic infection	Association of Applied Biologists, Descriptions of Plant Viruses
Unknown	*Datura stramonium* *Chenopodium amaranticolor*		Solanaceae Amaranthaceae - Chenopodiaceae	Plants	Sap inoculation	Local lesions; not systemic	ICTVd descriptions & Association of Applied Biologists, Descriptions of Plant Viruses
Unknown	*Eryngium aquaticum* *Eryngium planum*		Apiaceae / Umbelliferae	Plants	Sap inoculation	Systemic yellow flecksfollowed by symptomless infection of leaves	ICTVd descriptions & Association of Applied Biologists, Descriptions of Plant Viruses
Unknown	*Solanum lycopersicum cv. Rutgers*	Tomato	Solanaceae	Plants	Sap inoculation	Yellow mosaic with Australian isolate	ICTVd descriptions

Unknown	*Solanum lycopersicum*	Tomato	Solanaceae	Plants	Sap inoculation	No infection	Association of Applied Biologists, Descriptions of Plant Viruses
Unknown	*Nicotiana debneyi* *Nicotiana clevlandii*		Solanaceae	Plants	Sap inoculation	Symptomless local infection, systemic mosaic	Association of Applied Biologists, Descriptions of Plant Viruses

10. Which hosts are of economic and/or environmental importance in the PRA area?

The main hosts that are of economic importance in the UK are tomato (*S. lycopersicon*), *Capsicum* spp. (peppers), and a range of ornamentals. Information on production/value is given below:

Tomato
Tomato is a major crop in the UK and is mainly produced under protection.

Information quoted from the British Tomato Growers Association website (http://www.britishtomatoes.co.uk/facts/marketinfo.html - accessed 28 May 2012) showed that:

- British tomato production amounts to about 75,000 metric tonnes per year
- About 200 hectares of glasshouses are used to produce tomatoes in Britain
- The retail value of British tomato production is around £175 million

Provisional tomato production figures for the UK for 2010 from the Excel spreadsheet located on the Defra website accessed 28 May 2012 (Basic horticultural statistics uploaded 21 July 2011 http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-landuselivestock-hortstats-data-110721.xls) showed the following:

- Protected tomatoes (round, vine, plum and cherry) - 89.3 thousand tonnes home production marketed
- Protected tomatoes (round, vine, plum and cherry) – 213ha area planted

Capsicum spp.

Species in this genus are of increasing importance in the UK.

Provisional production figures for the UK for 2010 from the Excel spreadsheet located on the Defra website accessed 28 May 2012 (Basic horticultural statistics uploaded 21 July 2011 http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-landuselivestock-hortstats-data-110721.xls) showed the following:

- Protected sweet peppers – 19.2 thousand tonnes home production marketed
- Protected sweet peppers – 72ha planted area

Ornamentals

There are no specific details available on the Defra website for the species that are affected by this virus. Many of the known hosts are popular summer bedding/container plants in the UK.

11. If the pest needs a vector, is it present in the PRA area?

There are no known vectors of TMGMV. As with other tobamoviruses it is readily mechanically transmitted, by crop workers or their tools, and also transmitted by grafting. Evidence of seed transmission in *Capsicum chinense* has been found by RT-PCR and sequence analysis (Cordoba *et al*, 2006), but it is not thought to be transmitted by seed in *N. glauca* (Randles, 1981). The potential for transmission in tomato seed or seed of ornamentals has not been investigated/reported to date but such transmission may be possible based upon the mode of transmission of some of the related viruses in the same genus (tobamovirus) (see genus description; Brunt *et al*., 1996).

12. Describe the pathway(s) considered by this PRA[6]

The main pathways of entry are plants for planting of known natural hosts from countries where TMGMV is known to occur/has occurred (Australia, France (including Corsica), Germany, Iran, Israel, Italy, Korea, Madeira, Panama, Taiwan, Tunisia, USA, Venezuela).

Although the virus has been reported on different hosts in different countries it is assumed that the virus could be associated with any of the known host plants in the countries where it is known to occur.

The virus may occur in other countries (countries from which interceptions have occurred but where there are no records; the UK has intercepted the virus on plants from Belgium and Denmark) but there are no official records and so these cannot be considered to be pathways.

The known natural hosts comprise a number of ornamental species in which the virus is symptomatic (albeit there is no information on symptoms for *Tabernaemontana divaricata)* as well as *Capsicum* spp. and most recently tomato (*S. lycopersicon*).

Cultivated tobacco (*N. tabacum*) is also a host but there is no cropping area in the UK so it is presumed that there is no pathway. However, cigarettes may be a potential pathway of entry.

Seed transmission has been shown to occur in *Capsicum chinense* and such seed is therefore a potential pathway of entry. There is no information on seed transmission in *C. annuum* but as with other tobamoviruses it has the potential to be seed-transmitted in this host.

Seed transmission in tomato and ornamentals has not yet been proven. However, similar viruses (e.g. *Tomato mosaic virus*) in the same genus (Tobamovirus) are occasionally seed-transmitted so seed of these hosts has the potential (albeit unproven) to be a pathway of entry.

Experimentally-susceptible hosts may also represent pathways of entry but these have yet to be reported as natural hosts and so cannot be considered in this PRA.

The likelihood of entry is considered further for each pathway under section 13.

There are no specific phytosanitary requirements for TMGMV in the EC Plant Health Directive (Anon., 2000) that would directly affect entry of the virus into the UK. However, there are other EC phytosanitary requirements that will help reduce the risk of entry of TGMV to the UK. (See section 13.).

[6] A pathway description typically identifies a geographic origin, a host plant or plants and the intended use of the host. Other pathways including entry on other commodities or by natural means should be considered.

The pathways that are considered in 13 are listed below.

a. Plants for planting of ornamentals:
Calibrachoa spp., *Eryngium aquaticum, Eryngium planum,* Gesneriads (cultivated), *Impatiens* spp., *Nicotiana glauca* (tree tobacco), *Osteospermum* spp., *Petunia* spp., including *P. integrifolia* (trailing petunia/Surfinia), *Rhoeo spathacea, Tabernaemontana divaricata,* and *Torenia fournieri.*

b. Plants for planting of *Capsicum* spp. (*Capsicum annuum* (pepper), *C. chinense (*'Aji dulce' or 'Habanero chili' (chili pepper)

c. Plants for planting of tomato (*S. lycopersicon*)

d. Seed of *Capsicum* spp.

e. Seed of tomato (*S. lycopersicon*)

f. Seed of ornamentals:
Calibrachoa spp., *Eryngium aquaticum, Eryngium planum,* Gesneriads (cultivated), *Impatiens* spp., *Nicotiana glauca* (tree tobacco), *Osteospermum* spp., *Petunia* spp., including *P. integrifolia* (trailing petunia/Surfinia), *Rhoeo spathacea, Tabernaemontana divaricata,* and *Torenia fournieri*

g. Fruit of *Capsicum* spp.

h. Fruit of tomato (*S. lycopersicon*)

i. Cigarettes

13. How likely is the pest to enter the PRA area[7]?

The likelihood of entry for each of the pathways listed under 12. is given below. Pathways commence in the countries of origin where the virus has been reported: Australia, France (including Corsica), Germany, Iran, Israel, Italy, Korea, Madeira, Panama, Taiwan, Tunisia, USA, Venezuela. Although not all hosts are known to be infected in these countries for the purposes of this analysis it is presumed that the the virus could be associated with the known hosts. The amount of material imported for each pathway from each individual country of origin is uncertain.

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected ornamental plants for planting				X	

The main pathway on which TMGMV is likely to enter the UK is the movement of infected ornamental host plants from countries where the virus occurs. The virus has already previously entered the UK on infected ornamental host plants on two known occasions and there is therefore a likelihood of further entry. In the early stages of infection the plants may not show any symptoms or there may only be a few infected plants in a consignment and they may go undetected even if inspected. At the UK outbreak sites there were 2000

[7] Pest entry includes an assessment of the likelihood of transfer to a suitable host (ISPM No. 11, FAO, Rome)

impatiens, of which 5% were showing symptoms, and 20 osteospermum plants, of which 25% were symptomatic. A large number of ornamental plants for propagation are imported into the UK (albeit there are no specific data on the species known to become infected by this virus through the Defra website). This is a likely pathway as there have been several reported cases of TMGMV in a number of different ornamentals, from within and outside of Europe. However, some of the ornamental hosts belong to the Solanaceae family and plants for planting in this family, other than seeds, are prohibited entry from third countries other than European and Mediterranean countries.

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected *Capsicum* plants for planting			X		

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected tomato plants for planting			X		

Most *Capsicum* and tomato seedlings used in the UK are grown from seed, and Solanaceae plants for planting, other than seeds, are prohibited from third countries other than European and Mediterranean countries. Some seedlings are imported. TMGMV is not generally known in *Capsicum* and tomato crops in Europe, with all but one reported case on *Capsicum* being from outside the EU (one case in Italy - 1970; the rest in 3rd countries where the import is prohibited from with the exception of Tunisia where the virus was found in 2007/2008 – reported 2009) and only one case on tomato to date, in Iran in 2009/10 (reported 2011). Imports from Iran are prohibited. It is unknown how many, if any, *Capsicum* seedlings are imported by the UK from Tunisia, but Italy is known to have imported both *Capsicum* and *Solanum lycopersicum* (tomato) plantlets from Tunisia (EPPO Study on plants for planting, 2011). The presence of the virus in Tunisian *Capsicum* does raise the risk on this pathway. There is high uncertainty associated with the risk of entry on tomato plants from countries where they are permitted to be imported from because there is no information available on the distribution of the resistance gene to tobamoviruses in different tomato varieties.

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected seeds of *Capsicum*				X	

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected seeds of tomato			X		

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected seeds of ornamental hosts			X		

TMGMV may also enter the UK via infected seed for planting. The use of imported *Capsicum* and tomato seed is common in the UK and much of this seed is likely to have originated from outside Europe including countries where TMGMV has previously been

reported (e.g. USA and Taiwan). Seed transmission has been shown to occur in *Capsicum chinense* (Cordoba, 2006) and therefore this is a likely pathway. It is not known if TMGMV is seed-transmitted in other species of *Capsicum* or in tomato or ornamental hosts and further studies on seed transmission therefore need to be carried out. Thus there is high uncertainty associated with the risk of entry on seeds of tomato and ornamental hosts.

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected fruit of Capsicum			X		

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Infected fruit of tomato			X		

Fruit of *Capsicum* and tomato are potential pathways of entry for the virus which is transmitted via mechanical transmission albeit not proven by testing in this instance. Tomato has only been shown to be a host on one occasion to date and again the prevalence of the virus in tomato depends upon the presence/absence of the resistance gene which may vary with variety. At some UK tomato and *Capsicum* production nurseries, when home grown supplies are not sufficient to meet their needs, fruit is imported from outside the UK and packed on site. Therefore, infected fruit of both hosts is a possible pathway for TMGMV to enter the UK and to spread to plants at production sites. However, with the risk of *Pepino mosaic virus* (PepMV) also entering this way, precautions have been put in place at many nurseries to prevent this cross contamination. Infected fruit which is sold for consumption is unlikely to cause a problem.

	Very unlikely	Unlikely	Moderately likely	Likely	Very likely
Cigarettes (and dry tobacco)			X		

Another possible pathway is cigarettes and possibly dry tobacco. This is known to be a possible pathway for *Tobacco mosaic virus* (TMV), a closely related virus. Cigarettes (Brazilian) have been shown to contain TMGMV, as well as TMV, and this may act as a source of infection (Wetter, 1980) as workers smoke infected cigarettes and then touch and infect either tools or plants. To discover how likely this pathway is, investigations would need to be carried out into the proportion of commercial tobacco originating from areas with endemic TMGMV in tobacco crops which is imported to the UK.

14. How likely is the pest to establish outdoors in the PRA area?

Very unlikely	Unlikely	Moderately likely	Likely	Very likely
		X		

Neither *Capsicum* or tomato are generally grown commercially outdoors in the UK, therefore TMGMV is unlikely to become established outdoors in these crops. However, many ornamentals that are known to be hosts are grown outdoors in the UK and it is possible the virus could become established in these. Many of the hosts are bedding plants so overwintering will occur if infected plant debris is not completely removed. Mechanical transmission in the following season to plants that are known to be hosts could allow perpetuation of the virus.

In the summer in the UK, domestic gardeners grow tomatoes and *Capsicum* outdoors; the virus could possibly overwinter in crop debris if it is not removed.

TMGMV has become established outdoors in tropical and subtropical regions where *Nicotiana glauca* grows; it has also been found on this host in France (see Table 1). *N. glauca* is not widely present in the UK as it is not hardy enough for UK conditions, although it is sometimes grown in gardens. The Plants for a Future website (accessed June 14th 2012) http://www.pfaf.org/user/Plant.aspx?LatinName=Nicotiana+glauca states that: '*This species is hardy to about -5℃. Plants can survive the winter outdoors in the milder parts of Britain, though they usually act as herbaceous perennials in such conditions*'. TMGMV is also established in field tobacco in Germany (see Table 1). Weed species that are known to host TMGMV, including members of the Chenopodiacae and Umbelliferae are present in the UK, as well as other species of *Nicotiana*, and these could act as hosts. Although, TMGMV is reported to be widespread in field tobacco in Germany, there have been no reported outbreaks of TMGMV in *Capsicum*, tomato or ornamental crops there.

It is not known whether TMGMV would survive UK winter conditions in host plants, however tobamoviruses are generally very stable and are likely to survive if the host plant or plant debris survives and may survive in dried plant material (such as cigarettes) for a long time. TMGMV has been found to be less stable than *Tobacco mosaic virus* but is still very stable and is still infective in *N. glauca* after several years (DPV, 1989; unspecified conditions).

15. How likely is the pest to establish in protected environments in the PRA area?

Very unlikely		Unlikely		Moderately likely		Likely		Very likely	X

It is very likely that TMGMV could establish under protection in the UK. UK outbreaks in protected osteospermum and impatiens have already occurred. In the UK commercial crops of the natural hosts *Capsicum*, tomato and many ornamentals, are grown in protected environments. As glasshouse conditions are ideal, TMGMV could become widespread if no control measures were taken in glasshouses to prevent introduction, spread and carry-over between crops.

	Very unlikely		Unlikely		Moderately likely	X	Likely		Very likely	
Under protection:	Very unlikely		Unlikely		Moderately likely		Likely		Very likely	X

16. How quickly could the pest spread[8] within the PRA area?

TMGMV is easily transmitted mechanically and, once within a crop, is likely to spread quickly along rows and through the crop by plant to plant contact, the use of tools, and by handling during cultivation. The virus can be spread between different sites by workers, on their clothes and hands, if they work at more than one site. As nurseries often have a large number of plants and possibly a range of suitable hosts, which are often kept quite close together, spread from one plant to another is quite likely. Cuttings taken from infected mother plants are also likely to be infected.

[8] ISPM No 5. defines spread as the expansion of the geographic distribution of a pest within an area. Note that just because an organism can move or be transported quickly, does not mean that it will spread quickly, i.e. it also has to establish.

Although the virus is very likely to spread through a crop quickly, as there is no known vector it is unlikely to spread long distances naturally.

Long distance spread is most likely to be via the movement of infected young *Capsicum* or possibly tomato plants and ornamentals for planting, as well as possibly in infected seeds. However, the virus has only recently been reported on tomato and the prevalence of the resistance gene to tobamoviruses in UK tomato varieties is unknown. Seed transmission has only been proven in *C. chinense.*

	Very slowly	Slowly	Moderate pace	Quickly	Very quickly
Natural spread:	X				
In trade:				X	

17. Which part of the PRA area is the endangered area?

The endangered area is the protected cropping area for *Capsicum*, tomato and ornamentals (specified under hosts – Table 1) . In summer, outdoor plants either grown as crops or in gardens both public and private are endangered by TMGMV.

18. What is the pest's economic, environmental or social impact within its existing distribution?

There is little information available on this. The reported effects on infected *Capsicum* crops are quite mild; mild mosaic (Choi, 2002 and Font, 2009), curling and bubbling of the leaves (Cordoba, 2006) and mild chlorosis and necrotic lesions (Li, 2004). The symptoms seen in Panama on *Capsicum* were more severe, with ringspots, necrosis of the leaves, severe fruit distortion, leaf drop and death of the plants, however this was in mixed infections with one or more viruses (*Pepper mild mottle virus*, *Cucumber mosaic virus* and *Potato virus Y*) (Herrera-Vasquez, 2008). The commercial tomato crops infected with TMGMV in Iran showed symptoms of interveinal chlorosis, distortion and necrosis of the leaves and stem (Alishiri, 2011). The effects on tomato fruit were very severe, with necrosis and distortion. However, the percentage of tomato plants found to be infected in the field crops was quite low (about 9%) but the percentage of plants infected in glasshouses was much higher (F Rakhshandehroo, Islamic Azad University, Iran, personal communication, 2011). The symptoms on ornamentals make infected plants un-saleable. Further investigations need to be carried out into the effect of TMGMV on the yield and quality of *Capsicum* and tomatoes.

Very small	Small	Medium	Large	Very large
		X		

19. What is the pest's potential to cause economic, environmental or social impacts in the PRA area?

Pepper and tomato are economically important crops in the UK and therefore there is a risk of economic damage from TMGMV.

In recent years there has been a steady increase in pepper production in the UK, with over 70 hectares being grown in 2010 (19,000 tonnes of fruit). The value of the UK pepper industry was estimated to be £20 million in 2010 (Defra, 2010).

In 2010 approximately 213 hectares of tomatoes were planted, nearly 90,000 tonnes of fruit were produced and the value of the UK tomato industry was estimated to be £115 million (Defra, 2010). However, not all of these tomato crops would be at risk of infection from TMGMV. Further investigations would need to be carried out to determine the varieties that

can be infected with TMGMV and how many of these are grown commercially in the UK. However, it is not known whether it is possible to test for the resistance gene which would help determine how susceptible UK crops are. In Iran, the percentage of tomato plants found to be infected in the field crops was quite low, (about 9%), however the percentage of plants infected in glasshouses was much higher (F Rakhshandehroo, Islamic Azad University, Iran, personal communication, 2011). The fruit of the variety that was affected with TMGMV in Iran, were severely affected, if this was the case in the UK this would have a big economic impact, especially as in the UK there is very little tomato processing industry (i.e. most tomato fruit is sold directly for consumption).

There are no recent figures available for the UK ornamental industry including production figures by species, but in 2004 the total estimated value of the UK industry was £796 million, with flowers and bulbs produced in the open worth £31 million, hardy ornamental nursery stock £478 million and protected crops £287 million (Defra, 2010). The total ornamental export market in 2010 was approximately £48 million (Defra, 2010). Further work needs to be carried out on the host range of TMGMV to determine which of these ornamental hosts could be at risk of TMGMV infection.

The cost of containment and eradication if TMGMV was found in the UK is likely to be borne mainly by individual growers and the level of impact would depend where the pest was found – if just affecting a few ornamentals the impact would be minimal; if affecting a premium and widely grown tomato variety much larger. If TMGMV became listed as a quarantine pest by any country to which the UK exports fruit or plants, there is potential for loss of exports and / or additional costs being incurred to meet the importing country's phytosanitary requirements.

Very small		Small		Medium	X	Large		Very large	

20. What is the pest's potential as a vector of plant pathogens?
TMGMV is not a vector of plant pathogens.

STAGE 3: PEST RISK MANAGEMENT

21. How likely is the pest to continue to be excluded from the PRA area?

The scores below are given based upon the current status of phytosanitary measures.

	Very likely		Likely		Moderately likely		Unlikely	X	Very unlikely	
Under protection										
Outdoors	Very likely		Likely		Moderately likely	X	Unlikely		Very unlikely	

See the answers to question 13 summarised below. Exclusion will only occur if controls are put on the pathways of entry listed as having some potential for entry.

Ornamental plants are the most likely route by which the virus will enter (except prohibited Solanaceous ornamentals from third countries except European or Mediterranean countries). The virus has already entered via this route albeit outbreaks have been eradicated.

Pathways of entry are prohibited for tomato and *Capsicum* plants for planting from areas where the pest currently occurs with the exception of Tunisia.

Probabilities of entry of the virus from countries where the virus occurs are summarised below:

Infected ornamental plants for planting: *likely*
Infected *Capsicum* plants for planting (from permitted countries): *moderately likely*
Infected tomato plants for planting (from permitted countries): *moderately likely*
Infected seeds of *Capsicum: likely*
Infected seeds of tomato: *moderately likely*
Infected seeds of ornamental hosts: *moderately likely*
Infected fruit of *Capsicum*: *moderately likely*
Infected fruit of tomato: *moderately likely*
Contaminated cigarettes and dry tobacco: *moderately likely*

22. If the pest enters or has entered the PRA area how likely are outbreaks to be eradicated?

	Very likely	Likely	Moderately likely	Unlikely	Very unlikely
Under protection	[ ]	[X]	[ ]	[ ]	[ ]
Outdoors	[ ]	[ ]	[X]	[ ]	[ ]

It is likely that outbreaks could be successfully eradicated in protected crops and moderately likely outdoors.

23. If eradication is not possible, what management options are available for containment and/or non-statutory control?
Containment and/or non-statutory control relies firstly on detection of the virus in plants and seed (where known to be seed-transmitted) of known natural hosts. Detection in young plants may be difficult as it is not known how long symptoms are likely to take to appear in infected material. Seed transmission has only been proven to date in *C. chinense* and so before seed testing methodology is developed the potential for this to occur needs to be verified.

24. Conclusion and recommendations
Tobacco mild green mosaic virus has been reported on a range of hosts in: Australia, France (including Corsica), Germany, Iran, Israel, Italy, Korea, Madeira, Panama, Taiwan, Tunisia, USA, Venezuela. Not all hosts are known to be infected in these countries.

There have been two confirmed cases of the virus at UK nurseries on impatiens (in 2007) and osteospermum (in 2008) plants from the EU. Both outbreaks were eradicated, but there is concern that infected ornamental plants may act as a reservoir for infection of *Capsicum* and possibly tomato. Tomato has only recently been reported as a host (in Iran) and the susceptibility of UK tomato varieties to the

virus is unknown since the prevalence of the resistance gene to tobamoviruses in UK varieties is unknown.

Seed transmission has only been proven in *C. chinense* but may be possible from seed of ornamental hosts and tomato. However, this remains to be proven.

Fruit of tomato or pepper may also be a route of entry along with tobacco (dry) or in cigarettes.

TMGMV is not EC or EPPO listed and is therefore not currently subject to specific phytosanitary measures. The only pre-existing phytosanitary measure which will help prevent further entry to the UK is the prohibition of imports of plants for planting of Solanaceaous hosts other than seeds from third countries other than European and Mediterranean countries.

The most likely pathway of entry for this virus is on ornamental plants for planting from countries where the virus is known to occur. Ornamental plants are known to be symptomatic albeit the stage at which young plants exhibit symptoms is unknown.

The likelihood of entry on each of the pathways is summarised below:

Infected ornamental plants for planting: *likely*
Infected *Capsicum* plants for planting (from permitted countries): *moderately likely*
Infected tomato plants for planting (from permitted countries): *moderately likely*
Infected seeds of *Capsicum: likely*
Infected seeds of tomato: *moderately likely*
Infected seeds of ornamental hosts: *moderately likely*
Infected fruit of *Capsicum*: *moderately likely*
Infected fruit of tomato: *moderately likely*
Contaminated cigarettes and dry tobacco: *moderately likely*

It is may be possible to exclude TMGMV from the UK as although two outbreaks, one in osteospermum and one in impatiens have already occurred these have been eradicated.

To prevent TMGMV entering the UK, imported plants would have to be tested for the virus or come from a clean, certified stock or be produced in an area where TMGMV is known not to occur.

The importation of *Capsicum* and tomato plants (and solanaceous ornamentals) is prohibited except from other European and Mediterranean countries. There have been reports on some of these hosts (not tomato) within the permitted area. It is unknown what level of trade there may be with plants entering the UK, but this trade is unregulated and is also not subject to phytosanitary measures.

Seed of all the known hosts can enter freely and although seed transmission has only been proven in *C. chinense*; if it is proven in other hosts then controls on entry would depend upon the development of sampling and testing procedures for seed from countries where the virus is known to occur.

There are no restrictions on the movement of tomato or pepper fruit from third countries, therefore infected fruit from outside Europe where the virus occurs could

be imported into the UK. As a precaution imported fruit should be packed in areas away from growing plants, measures should be put in place to prevent cross contamination and workers should be separated to minimise the risk of spread from infected fruit to growing plants. These precautions are already in place at many tomato nurseries because of the risk from *Pepino mosaic virus*.

The virus is very likely to establish under protection and moderately likely outside, if no control measures are taken.

Economic impact is likely to be '*medium*' but with a degree of uncertainty. Further investigations need to be carried out into the varieties of tomatoes that can be infected and the effect of TMGMV on Capsicum and tomato fruit quality and yield. Ornamental hosts are symptomatic and so the effect of the virus on plant quality will have negative economic impact.

The endangered area is *Capsicum,* tomato and ornamental hosts, especially protected crops but also plants grown outdoors in the summer.

In a glasshouse situation the prospects of eradication are quite good especially as there is no insect vector involved in transmission. Success would depend on how early the outbreak was discovered and how quickly the virus can spread. It is likely the virus could at least be contained during the growing season and eradicated at the end of the season. The virus is likely to spread quickly through a crop by mechanical means. Therefore, infected plants and a large area around them would need to be cordoned off and not touched. Remaining plants would then need to be regularly inspected for virus symptoms and any suspects tested. Fruit of tomatoes and peppers, if marketable, could be allowed to be sent for retail.

Good hygiene practices would prevent the virus spreading between plant batches and re-infecting clean material. All tools, equipment and surfaces would need to be thoroughly cleaned with hot water and then disinfected. There is no disinfection data specifically on TMGMV, but disinfectants that have been shown to work on other viruses, including *Tobacco mosaic virus* and *Pepino mosaic virus,* are likely to work. Glasshouse workers should wear disposable protective clothing, including gloves, coats and shoe covers and these should be changed regularly.

At the end of the season to prevent carry over the glasshouse should be thoroughly cleaned and disinfected, making sure that no plant debris or weeds are left remaining, before a new crop is planted. Virus indexing of mother stocks would help prevent re-infection.

Following a cleanup at both nurseries where the UK outbreaks occurred, there have been no further cases at either site.

At nurseries, ornamental hosts should be kept separate from *Capsicum* or tomato crops, to make sure the virus does not spread from possibly infected ornamentals.

An outbreak in a field crop may be more difficult to eradicate, especially as a number of weed species have been identified as hosts of TMGMV and have the potential to harbour the virus in field crops.

It may be possible to exclude TMGMV from further entry to the UK. Recommendation of the consideration of possible measures on the pathways of

entry to prevent entry would include the requirement for plants and possibly seeds of the known hosts that are permitted entry to the UK to originate in countries or areas where the virus is known not to occur or from pest-free places of production. Controls on fruit of *Capsicum* and tomato could also be considered.

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Authors: Anna Skelton and Claire Sansford

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Version no.: 4

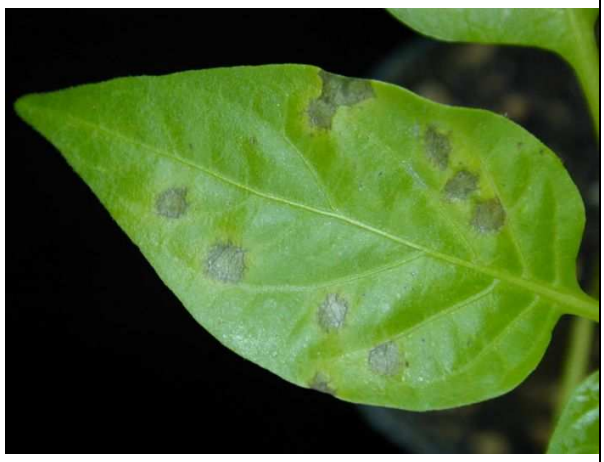
Author: Anna Skelton

Reviewers: Alan MacLeod, Richard Baker, Helen Anderson, Neil Giltrap, Peter Reed and Sharon Matthews-Berry.

Further work that would help reduce uncertainties

Section of rapid assessment	Uncertainties	Further work that would reduce uncertainty
Taxonomy		
Distribution	The distribution of TMGMV is uncertain, especially as in many countries many wild plants/ weeds may be infected but have not been tested.	Carry out surveys of known infected hosts.
Hosts	TMGMV infects many hosts but it probably has a larger host range than we know about.	Further host range studies should be carried out, especially on different tomato varieties to determine which are susceptible to TMGMV. Also carry out a survey of Nicotiana and other weed species in the UK to investigate if TMGMV is present.
Pathways	It is not known whether seed transmission occurs in tomatoes and ornamentals.	Investigate seed transmission in tomatoes and affected ornamentals.
Establishment	Not known if TMGMV can overwinter in host plants or dried leaf material.	Carry out experiments to see if TMGMV can survive UK winter conditions.
Spread	How quickly the virus would spread through a crop is uncertain.	Investigate how quickly the virus would spread through *Capsicum*, tomato and ornamental crops.
Impact	Not known what affect the virus has on the yield and quality of *Capsicum* and tomato crops. Not known which tomato varieties may be most at risk – some varieties are believed to carry resistance genes.	Carry out trials to determine the yield and quality losses of *Capsicum* and tomato. Trails to investigate susceptible tomato varieties.
Management	-	-

19. IMAGES OF PEST

	
Symptoms of TMGMV in tomato Source/ copyright owner: **Farshad Rakhshandehroo & Mrs Athar Alishiri,** Department of Plant Pathology, College of Agriculture and Natural Resources, Science and Research Branch, Islamic Azad University, Tehran, Iran	Symptoms of TMGMV in *Capsicum annum* Source/ copyright owner: **Ya-Chun Chang & Ms. Ching-Yun Li,** Department of Plant Pathology and Microbiology, National Taiwan University, Taipei, Taiwan

	
TMGMV in Osteospermum Fera sample	TMGMV in Osteospermum Fera sample

Symptoms of TMGMV in tomato fruit

Source/ copyright owner: **Farshad Rakhshandehroo & Mrs Athar Alishiri,** Department of Plant Pathology, College of Agriculture and Natural Resources, Science and Research Branch, Islamic Azad University, Tehran, Iran

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

Given the limited amount of information currently available and the level of uncertainty regarding the potential damage to tomatoes, the information presented here is considered to provide sufficient justification for continued action. However in the event of further information on TMGMV becoming available or there being a dramatic increase in the number of outbreaks in ornamentals (or indeed) tomatoes then it will be important to review action being taken.

Yes Statutory action	X	No Statutory action	

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