Netherlands Food and Consumer
Product Safety Authority
Ministry of Agriculture,
Nature and Food Quality

Quick scan National Plant Protection Organization, the Netherlands

Quick scan number: 2020VIR001

Quick scan date: 4 November 2020

No.	Question	Quick scan answer for Tomato mottle mosaic virus
1.	What is the scientific name (if possible up to species level + author, also include (sub)family and order) and English/common name of the organism? *Add picture of organism/damage if available and publication allowed*.	*Tomato mottle mosaic virus* (ToMMV), genus *Tobamovirus*, family *Virgaviridae*
2.	What prompted this quick scan? *Organism detected in produce for import, export, in cultivation, nature, mentioned in publications, e.g. EPPO alert list, etc.*	ToMMV is (currently) not regulated in the EU. For the related tobamovirus tomato brown rugose fruit virus (ToBRFV), however, emergency measures have been in place since November 2019 (EU, 2019 and 2020). ToBRFV has been found causing damage to tomato and pepper crops in the EU since it is able to overcome resistances of current cultivars (Luria et al., 2017). The fact that ToMMV shares characteristics with ToBRFV (Li et al., 2017), is reason for drafting this quick scan. In addition, Australia has implemented emergency measures for ToMMV and requires tomato and pepper seed lots to be imported, to be tested and found free from this virus (https://www.agriculture.gov.au/import/goods/plant-products/seeds-for-sowing/emergency-measures-tommv-qa#what-is-tomato-mottle-mosaic-virus-tommv).
3.	What is the current area of distribution?	CABI distribution map, retrieved 7-7-2020, 11-6-2020

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		 **Present in** Asia: China (Li et al., 2014), Iran, Israel (Turina et al., 2016) Europe: Spain (Ambros et al., 2017) America: Brasil (Nagai et al., 2018) Mexico (Li et al., 2013) USA (Webster et al., 2014) ToMMV may have a wider distribution than currently known. ToMMV was detected in tomato seed lots to be imported into Australia (origin not mentioned) (Lovelock et al., 2020) and in tomato seed lots in Czech Republic and United Kingdom (Michal Hnizdil, Central Institute for Supervising and Testing in Agriculture, pers. comm.). The seeds that tested positive in Czech Republic had been imported from China and the seeds in UK had been imported from the USA but originated from India. Additionally, plants tested positive for ToMMV in Czech Republic that had been raised from seeds produced in Czech republic (Michal Hnizdil, Central Institute for Supervising and Testing in Agriculture pers. comm.).
4.	What are the host plants?	Natural hosts of ToMMV are *Capsicum annuum, Capsicum frutescens*, *Solanum lycopersicum* and *Solanum melongana* (Chai et al., 2018; Li et al., 2013; Li et al., 2017). In *Solanum melongena*, a mixed infection of ToMMV and tobacco mild green mosaic virus (TMGMV) has been reported (Chai et al., 2018). Infection of *Cicer arietinum* was once reported in Italy, but needs confirmation (Pirovano., 2015). Experimental hosts: *Arabidopsis thaliana, Brassica campestris, Brassica chinensis, Brassica oleacea, Brassica oleracea, Brassica pekinensis, Chenopodium quinoa, Datura stramonium, Glebionis coronaria, Gomphrena globose, Nicandria physaloides, Nicotiana benthamiana, Nicotiana rustica, Nicotiana tabacum, Petunia hybridia, Physalis alkekengi, Physalis angulate, Physalis pubescens, Raphanus sativus, Solanum nigrum, Verbena officinalis* (Ambros et al., 2017; Li et al., 2017; Sui et al., 2017).
	Does the organism cause any kind of plant damage in the current area of distribution and/or does the consignment demonstrate damage suspected to have been caused by this organism? *Yes/no + plant species on which damage has been reported + short description of symptoms.* *Please indicate also when the organism is otherwise harmful (e.g.*	The following symptoms have been reported in natural hosts of ToMMV: - *C. annuum:* plants show apical yellowing and necrosis. Leaves show mosaic and crinkling (Ambros et al., 2017; Zhan et al., 2018) - *C. frutescens:* leaves show mottle, shrinking and necrosis (Li et al., 2017). - *S. lycopersicum*: plants are stunted, leaves show severe mosaic, mottle, distortion and necrosis, fruits show necrotic lesions and fruit necrosis (Li et al., 2013; Sui et al., 2017; Zhan et al., 2018). - *S. melongena*: flowers show dark purple mottle, leaves show mosaic distortion. These symptoms were present in plants with a mixed infection with ToMMV and TMGMV (Chai et al., 2018) - *C. arietinum:* no symptoms observed (Pirovano, 2015)

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	predator, human/veterinary pathogen vector, etc.).	
6.	Assess the probability of establishment in the Netherlands (NL) (i.e. the suitability of the environment for establishment). a. In greenhouses b. Outdoors c. Otherwise (e.g. storage facilities, human environment)	a) High: the hosts *C. annuum* and *S. lycopersicum* are widely cultivated in greenhouses in the Netherlands. In addition, the biology of the virus is very similar to ToBRFV (Li et al., 2017), which is currently under eradication. b) Low: *C. annuum* and *S. lycopersicum* are not commercially cultivated outdoors in the Netherlands. However, experimental hosts *Arabidopsis thaliana, Solanum nigrum* and *Verbena officinalis* are common weeds in the Netherlands and could potentially act as reservoirs for the virus. c) Not applicable.
7.	Assess the probability of establishment in the EU (i.e. the suitability of the environment for establishment).	High, *C. annuum* and *S. lycopersicum* are cultivated indoors throughout the EU and additionally outdoors in parts of the EU.
8.	What are the possible pathways that can contribute to spread of the organism after introduction? How rapid is the organism expected to spread (by natural dispersal and human activity)?	Pathways that can contribute to spread include: 1) mechanical transmission; 2) plants for planting ((A) plants and (B) seeds); 3) possible spreading via bumblebees; 4) fruit. 1) Mechanical transmission: tobamoviruses are notorious for the rapid spread by mechanical transmission when handling the plants in the greenhouse. They are also known for their stability and can survive for a long time on surfaces. The virus can be transferred from surfaces to infect plants (Dombrovsky & Smith., 2017). 2) A) Plants: the virus can be spread via plants for planting, just like ToBRFV, ToMV and TMV (Dombrovsky & Smith., 2017). B) Seeds: Since it is a tobamovirus, the virus is likely to spread via seeds (Dombrovsky & Smith., 2017). ToMMV has already been found on seeds of *C. annuum* (Lovelock et al., 2020) and *S. lycopersicum* (Turina et al., 2016). 3) Like ToBRFV (Levitzky et al., 2019) ToMMV might be spread via bumblebees. 4) No records available of fruits that tested positive for ToMMV. However, presence of ToMMV in fruit can be expected, based on symptoms on fruits of infected *S. lycopersicum* (Sui et al., 2017), reports of ToMMV present in seed lots (Lovelock et al., 2020 & Turina et al., 2016) and high virus concentrations reported in fruit for the related ToBRFV and other tobamoviruses (Dombrovsky et al., 2017; Klap et al., 2020; Salem et al., 2020). Mechanical transmission, transmission by bumble bees and trade of young plants would mainly contribute to local and regional spread of the virus, while trade of seeds and possibly trade of fruits may lead to global spread of the virus. The virus can spread rapidly due to its presumably high infectivity unless (most of the) cultivars that are grown in the EU are resistant against the virus . The level of resistance of cultivars grown in the EU, is, however, uncertain (see also Question 9).

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9.	Provide an assessment of the type and amount of direct and indirect damage (e.g. lower quality, lower production, export restrictions, threat to biodiversity, etc.) likely to occur if the organism would become established in NL and the EU, respectively?	ToMMV has shown to break resistance of tomato cultivars that were resistant to tomato mosaic virus (ToMV) (Sui et al., 2017). However, Nagai et al., 2019 indicated that the resistance gene $Tm2^2$ confers resistance to ToMMV. It should be noted, however, that 5 out of 10 $Tm2^2$ plants tested positive for the virus using ELISA, although in much lower levels than the plants lacking $Tm2^2$. One of the $Tm2^2$ plants showed virus symptoms. According to Nagai et al.(2019) many tomato cultivars and hybrid lines are susceptible to ToMMV. Currently, there are no records available of resistance to ToMMV in *C. annuum*. However, it is estimated by Dutch breeding companies that nearly 100% of the tomato and pepper cultivars grown in the Netherlands are resistant to ToMMV and they do not consider ToMMV as an emerging threat (Information from Plantum, Dutch association for the plant reproduction material sector,, https://plantum.nl/, September 2020). The virus has been recorded in the EU in a research greenhouse in Spain in 2015 for the first time (Ambros et al., 2017). Since then, no information has become available about yield losses due to this virus in tomato or *pepper* crops in the EU. The related virus ToBRFV which appears to be a more recently 'discovered' species than ToMMV has already been found in more than 20 greenhouses in the Netherland whereas ToMMV has thus far not been detected during surveys for ToBRFV. Taking into account that tobamoviruses are known to spread very rapidly and can cause potentially high yield losses in susceptible crops, it seems that the majority of host crops in the EU are not highly susceptible or sensitive to this virus. However, without any data on the resistance against ToMMV of the crops used in the EU, this assessment remains uncertain.
10.	Has the organism been detected on/in a product other than plants for planting (e.g. cut flowers, fruit, vegetables)? *If "no", go to question 12*	No
11.	If the organism has been found on/in a product other than plants for planting (e.g. cut flowers, fruit, vegetables), what is the probability of introduction (entry + establishment)? *Only to be answered in case of an interception or a find.*	
12.	Additional remarks	
13.	References	Ambros, S., Martinez, F., Ivars, P., Hernandez, C., de la Iglesia, F., & Elena, S. F. (2017). Molecular and biological characterization of an isolate of Tomato mottle mosaic virus (ToMMV) infecting tomato and other experimental hosts in eastern Spain. *European Journal of Plant Pathology*, *149*(2), 261-268.

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		Chai, A. L., Chen, L. D., Li, B. J., Xie, X. W., & Shi, Y. X. (2018). First report of a mixed infection of Tomato mottle mosaic virus and Tobacco mild green mosaic virus on Eggplants in China. *Plant Disease*, *102*(12), 2668-2668. Dombrovsky, A., Tran-Nguyen, L. T., & Jones, R. A. (2017). Cucumber green mottle mosaic virus: rapidly increasing global distribution, etiology, epidemiology, and management. Annual review of phytopathology, 55, 231-256. Dombrovsky, A., & Smith, E. (2017). Seed transmission of Tobamoviruses: Aspects of global disease distribution. *Advances in Seed Biology. London, UK: IntechOpen*, 233-60. European Food Safety Authority (EFSA). (2019). Plant Health Newsletter: Media Monitoring No. 32. *EFSA Supporting Publications*, *16*(12), 1755E. EU (2019). COMMISSION IMPLEMENTING DECISION (EU) 2019/1615 of 26 September 2019 establishing emergency measures to prevent the introduction into and the spread within the Union of Tomato brown rugose fruit virus (ToBRFV). EU (2020). COMMISSION IMPLEMENTING REGULATION (EU) 2020/1191 of 11 August 2020 establishing measures to prevent the introduction into and the spread within the Union of Tomato brown rugose fruit virus (ToBRFV) and repealing Implementing Decision (EU) 2019/1615. Jukema, G. D. (2017). Nederlandse handel in tomaten. Klap, C., Luria, N., Smith, E., Bakelman, E., Belausov, E., Laskar, O., ... & Dombrovsky, A. (2020). The Potential Risk of Plant-Virus Disease Initiation by Infected Tomatoes. Plants, 9(5), 623. Levitzky, N., Smith, E., Lachman, O., Luria, N., Mizrahi, Y., Bakelman, H., ... & Dombrovsky, A. (2019). The bumblebee Bombus terrestris carries a primary inoculum of Tomato brown rugose fruit virus contributing to disease spread in tomatoes. *PLoS One*, *14*(1), e0210871. Li, R., Gao, S., Fei, Z., & Ling, K. S. (2013). Complete genome sequence of a new tobamovirus naturally infecting tomatoes in Mexico. *Genome announcements*, *1*(5). Li, Y. Y., Wang, C. L., Xiang, D., Li, R. H., Liu, Y., & Li, F. (2014). First report of tomato mottle mosaic virus infection of pepper in China. *Plant Disease*, *98*(10), 1447-1447. Li, Y., Wang, Y., Hu, J., Xiao, L., Tan, G., Lan, P., ... & Li, F. (2017). The complete genome sequence, occurrence and host range of Tomato mottle mosaic virus Chinese isolate. *Virology journal*, *14*(1), 15. Lovelock, D. A., Kinoti, W. M., Bottcher, C., Wildman, O., Dall, D., Rodoni, B. C., & Constable, F. E. (2020). Tomato mottle mosaic virus intercepted by Australian biosecurity in Capsicum annuum seed. *Australasian Plant Disease Notes*, *15*(1), 8. Luria, N., Smith, E., Reingold, V., Bekelman, I., Lapidot, M., Levin, I., ... & Ezra, N. (2017). A new Israeli Tobamovirus isolate infects tomato plants harboring Tm-22 resistance genes. PloS one, 12(1), e0170429. Nagai, A., Duarte, L. M., Chaves, A. L., Alexandre, M. A., Ramos-González, P. L., Chabi-Jesus, C., ... & Dos Santos, D. Y. (2018). First complete genome sequence of an isolate of tomato mottle mosaic virus infecting plants of Solanum lycopersicum in South America. *Genome Announcements*, *6*(19). Nagai, A., Duarte, L. M., Chaves, A. L., Peres, L. E., & dos Santos, D. Y. (2019). Tomato mottle mosaic virus in Brazil and its relationship with Tm-2 2 gene. *European Journal of Plant Pathology*, *155*(1), 353-359.

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		Ramaekers, P., Dolman, M., & Jukema, G. (2018). De Nederlandse landbouwexport 2017. Centraal Bureau voor de Statistiek.Pirovano, W., Miozzi, L., Boetzer, M., & Pantaleo, V. (2015). Bioinformatics approaches for viral metagenomics in plants using short RNAs: model case of study and application to a Cicer arietinum population. *Frontiers in microbiology*, *5*, 790. Salem, N. M., Cao, M. J., Odeh, S., Turina, M., & Tahzima, R. (2020). First Report of Tobacco Mild Green Mosaic Virus and Tomato Brown Rugose Fruit Virus Infecting Capsicum annuum in Jordan. Plant Disease, 104(2), 601. Sui, X., Zheng, Y., Li, R., Padmanabhan, C., Tian, T., Groth-Helms, D., ... & Ling, K. S. (2017). Molecular and Biological Characterization of Tomato mottle mosaic virus and Development of RT-PCR Detection. *Plant disease*, *101*(5), 704-711. Turina, M., Geraats, B. P. J., & Ciuffo, M. (2016). First report of Tomato mottle mosaic virus in tomato crops in Israel. *New Dis Rep*, *33*(1), 2044-0588. Webster, C. G., Rosskopf, E. N., Lucas, L., Mellinger, H. C., & Adkins, S. (2014). First report of tomato mottle mosaic virus infecting tomato in the United States. *Plant Health Progress*, *15*(4), 151-152. Zhan, B. H., Ning, C. A. O., Wang, G, K. N., & Zhou, X. P. (2018). Detection and characterization of an isolate of Tomato mottle mosaic virus infecting tomato in China. *Journal of Integrative Agriculture*, *17*(5), 1207-1212.
14.	**Conclusions**	This Quickscan was prompted by reports on a relatively new tobamovirus, tomato mottle mosaic virus (ToMMV), that was found in the EU in 2015 for the first time. It can infect tomato, *Capsicum* and eggplant. It is related to tomato brown rugose fruit virus (ToBRFV) that breaks all known resistance genes/alleles in commercial tomato cultivars and is regulated in the EU since November 2019. ToMMV has also shown to break resistance of tomato cultivars that are resistant to tomato mosaic virus (ToMV). However, no yield losses have thus far been reported in commercial crops in the EU due to ToMMV and many cultivars may be (partially) resistant against ToMMV. Therefore, it seems that ToMMV is much less of a threat than ToBRFV for which many outbreaks have already been reported.
15.	**Follow-up measures**	ToMMV will be included in the national survey program to determine the pest status in the Netherlands.