2023-2025

ISF ToMMV

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GEVES

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ISF combined effort on validation of tomato mottle mosaic virus (ToMMV) differential host set on tomato and pepper

Abstract
Tomato mottle mosaic virus (*Tobamovirus*, ToMMV) was first described in Mexico in 2013 from *S. lycopersicum* samples taken in 2009. This emerging virus is closely related to tomato mosaic virus (ToMV) and can naturally affect tomato and capsicum and can be mechanically transmitted to other Solanaceae (*Nicotiana* spp., *Petunia hybrida*, *Physalis* spp.) and Brassicaceae.
A previous work performed by GEVES of characterization of ToMMV on tomato and pepper differentials allowed to establish a draft of the pattern of ToMMV on Tobamovirus differentials. The ISF ToMMV project has confirmed that pattern and proposed a differential set for ToMMV a tomato and pepper.

Background

Tomato mottle mosaic virus (ToMMV) is a member of the *Tobamovirus* genus. It is transmitted through propagation materials (seeds, plants for planting, grafts, cuttings), and spreads locally by contact including direct plant-to-plant contact, contaminated tools, hands, or clothing and by bees.
ToMMV has been described infecting tomato and pepper plants in several countries worldwide (Li et al, 2013; Tettey et al. 2022), resulting in unmarketable fruit. On tomato, symptoms include severe necrotic lesions, chlorosis, leaf distortion, mottle and systemic crinkling symptoms and fruit necrosis (Ambros et al, 2017). On capsicum, symptoms include foliar mottle, shrinking and necrosis.
On tomato, the *Tm-2*^{2} resistance gene confers the resistance to ToMMV (Tettey et al 2023). On pepper the *L* resistance gene (*L1, L2, L3, L4*) confers resistance against Tobamovirus species. But the resistance of these *L* resistance genes to ToMMV is not clear (Tettey et al, 2023).

In a previous work, GEVES tested a ToMMV isolate on the tomato and pepper Tobamovirus differentials (Annexes 1 and 2). On tomato, differentials carrying on the *Tm2* and *Tm2*^{2} resistance gene were observed as resistant to ToMMV. On pepper, differentials carrying on *L1, L2, L3* and *L4* resistance gene were observed as resistant to ToMMV.

The ISF ToMMV project group has validated the characterization of ToMMV isolate of tomato and pepper Tobamovirus differentials. The ISF project group consisted of representatives of the companies BASF, Bejo Zaden, Enza Zaden, Gautier, Rijk Zwaan, Sakata Seed America, Sakata Seed Corporation and Takii, and the examination office GEVES (Table 1). They validated the differential sets by ring test using the CPVO technical protocols (Annexes 3 and 4).

Table 1: list of participants to the ISF ToMMF project

Company name	Contact person	Email address
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Sakata Seed Corporation	Sentaro Mizogushi Kazunori Murao	s-mizoguchi@sakata-seed.co.jp k.murao@sakata-seed.co.jp
Takii Japan	Ryohei Arimoto Ito Tomoki	arimoto@takii.co.jp tomoki-ito@takii.co.jp

Materials and methods

The ToMMV isolate used in the ring test was sampled on *Solanum lycopersicum* in California. The isolate was multiplied by GEVES and sent to each participant.
The seeds of the tomato and pepper differentials were supplied by the MatRef network (Table 2) and the same seed lot for each variety was sent the participant by GEVES.

Table 2: Tomato and pepper Tobamovirus differentials used for ToMMV characterization

Tomato differentials	Pepper differentials
Monalbo	Lamu
Mobaci	Yolo Wonder
Momor	Tabasco
Moperou 161	Novi 3
	Tom 4

Tests were performed following the CPVO tomato technical protocol for evaluation of the resistance to ToMV and the pepper technical protocol for evaluation of the resistance to TMV on two replicates of 10 plants per differential.

Results and discussion

8 results out of the 9 expected were received and analysed for tomato and pepper.

Results on tomato differential set
For tomato, globally a good concordance of interpretation was observed between laboratories (Table 3). Discrepancies were observed only for the differential Momor.

Table 3: lab's interpretation of tomato differentials tested with ToMMV isolate

Tomato	Monalbo	Mobaci	Momor	Moperou 161
Lab 1	S	S	HR	HR
Lab 2	S	S	SEG	HR
Lab 3	S	S	HR	HR
Lab 4	S	S	HR	HR
Lab 5	S	S	HR	HR
Lab 6	S	S	HR	HR
Lab 8	S	S	HR	HR
Lab 9	S	S	HR	HR

S: susceptible; HR: high resistant; SEG: segregation

In lab 2, 8 plants out of 20 of Momor were observed susceptible and the variety was judged in segregation. The off-type plants of the differential Momor observed with symptoms were tested for the presence of resistance gene by marker. The presence of *Tm2²* was confirmed in these susceptible plants. The potential cause of susceptibility on few plants could be a lab effect as this result was not observed in the other labs.
Monalbo and Mobaci (*Tm1*) were confirmed susceptible and Moperou 161 (*Tm2*) and Momor (*Tm2²*) were confirmed resistant (Table 4). These results are correlated with the previous results observed by GEVES.

Table 4: characterization of the ToMMV isolate ion tomato differentials

Differentials	**ISF Code and races** **Gene (s)**	**ToMMV**
Monalbo*, Marmande* Early Pak 7*	-	S
Mobaci*	*Tm*	S
Moperou 161*	*Tm2*	HR
Momor*, Geneva 80, Gourmet	*Tm2²*	HR

S: susceptible; HR: high resistant

Results on pepper differential set
For pepper, globally a good concordance of interpretation was observed between laboratories (Table 5). Discrepancies were observed only for the differential Tom 4.

Table 5: lab's interpretation of pepper differentials tested with ToMMV isolate

Pepper	**Lamu**	**Yolo Wonder**	**Tabasco**	**Novi 3**	**Tom 4**
Lab 1	S	R	R	R	R
Lab 2	S	R	R	R	SEG
Lab 3	S	R	R	R	R
Lab 4	S	R	R	R	R
Lab 5	S	R	R	R	R
Lab 6	S	R	R	R	R
Lab 8	S	R	R	R	R
Lab 9	S	R	R	R	R

S: susceptible; HR: high resistant; SEG: segregation

In lab 2, 3 plants out of 18 of Tom 4 were observed susceptible and the variety was judged in segregation. The plants of the differential Tom 4 in lab 2 were tested for detection of resistance gene. Results shown that no *L4* resistance gene was detected in the susceptible plants. And no plant with *L4* was susceptible. The hypothesis is that the line is not 100% homogeneous, even if it was not observed in the other labs. The conclusion is that there is no mismatch between the resistance pattern and the *L4* resistance gene.
Lamu (*L0*) was confirmed susceptible, and Yolo Wonder (*L1*), Tabasco (*L2*), Novi 3 (*L3*) and Tom 4 (*L4*) were confirmed resistant (Table 6). These results confirmed the previous results observed by GEVES.

Table 6: characterization of the ToMMV isolate ion pepper differentials

	Pepper Tobamovirus Group	**Tm:0**
	ISF Code and races →	ToMMV
Differential hosts	**Gene**	
Lamu, Early Calwonder	*L0*	S
Tisana, Yolo Wonder	*L1*	HR
Tabasco (*C. frutescens*)	*L2*	HR
Solario F1, Novi 3, PI159236 (*C. chinense*)	*L3*	HR
Tom4, CAPMVR, PI260429 (*C. chacoense*)	*L4*	HR

S: susceptible; HR: high resistant

Absence of variation in ToMMV isolates

Another ToMMV isolate was tested by one of the labs on the tomato and pepper differentials. The results on both species confirmed the results observed in the ring test. This additional test confirmed that no difference of pattern is expected depending on different ToMMV isolate.

Conclusions

The results are consistent among labs to conclude on the disease reaction with ToMMV on the tomato and pepper differentials. The following proposals were made by the group for the differential sets:

- To create a new differential set on tomato for ToMMV to avoid any misunderstanding with other Tobamovirus (annex 5).
- To include ToMMV in the current pepper Tobamovirus differential set (annex 6).

Publication of the results

References

Ambros S. et al. (2017). Molecular and biological characterization of an isolate of Tomato mottle mosaic virus (ToMMV) infecting tomato and other experimental hosts in eastern Spain. Eur J Plant Pathol., DOI 10.1007/s10658-017-1180-2

Li, R., Gao, S., Fei, Z. and Ling, K.S. (2013). Complete genome sequence of a new tobamovirus naturally infecting tomatoes in Mexico. Genome announcements, 1(5): e00794-13

Tettey C. K. et al, (2022). Tomato mottle mosaic virus: Characterization, resistance gene effectiveness, and quintuplex RT-PCR detection system. Journal of Integrative Agriculture, Volume 21, Issue 9, Pages 2641-2651. https://doi.org/10.1016/j.jia.2022.07.020.

Tettey C. K. et al, (2023). The role of different innate and environmental factors in Tm-2^2-mediated resistance to tomato mottle mosaic virus. Phytopathology Research, Volume 5, Issue 8.

Annex 1: tomato ToMV differential sets

International Seed Federation
Seed is Life

Nyon, Switzerland
July 2019

Differential Sets

Tomato mosaic virus (ToMV) - **Tomato**

Differential hosts	Gene present	Race		
		ToMV: 0*	ToMV: 1*	ToMV: 2*
Monalbo*, Marmande* Early Pak 7*	-	S	S	S
Mobaci*	*Tm*	HR	S	HR
Moperou 161*	*Tm2*	HR	HR	S
Momor*, Geneva 80, Gourmet	*Tm2²*	HR	HR	HR

S = susceptible; HR = highly resistant

* differential hosts and isolates that are used by the seed sector.

Note: Strains ToMV: 1.2 and ToMV: 2² described in literature are not included in this table. Strain 1.2 is very exceptional and 2² is a necrotic strain associated with *Tm2²* obtained in the lab and is therefore not seen in nature.

References

Pelham, J. (1969) Isogenic lines to identify physiologic strains of TMV. *Tomato Genet. Coop. Rep.* 19:18.

Rast, A. T. B. (1975) Variability of tobacco mosaic virus in relation to control of tomato mosaic in greenhouse tomato crops by resistance breeding and cross protection. *Cent. Agric. Publ. Doc. Agric. Res. Rep.* 834. 76pp.

Waterson, J. C. (1993). Development and breeding of resistance to pepper and tomato viruses. In: Resistance to viral diseases of vegetables. Genetics & Breeding. Ed. M. M. Kyle. pp 80-101. Timber Press, Portland

Protocol

CPVO. See http://www.cpvo.europa.eu/ for a protocol on disease resistance testing

For more information contact the ISF Secretariat at isf@worldseed.org

Annex 2: pepper Tobamovirus differential sets

International Seed Federation
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Nyon, Switzerland
June 2024

Differential Set

Tobamoviruses *(Tobacco mosaic virus* (TMV), *Tomato mosaic virus* (ToMV), *Tobacco mild green mosaic virus* (TMGMV), *Paprika mild mottle virus* (PaMMV), *Pepper mild mottle virus* (PMMoV) *and Bell pepper mottle virus* (BPMoV)- **Pepper**

The genus *Tobamovirus* includes multiple species that are pathogenic on *Capsicum* spp including the type species *Tobacco mosaic virus* (TMV), and the serologically related *Tomato mosaic virus* (ToMV), *Pepper mild mottle virus* (PMMoV) and several other plant viruses.
The nomenclature of Tobamoviruses has been the subject to several revisions in the period between 1980 and 2004. International Committee on Taxonomy of Viruses (ICTV) is the standard reference for virus taxonomy. More information can be found in the ICTV master species list https://talk.ictvonline.org/

Resistance is governed by four different dominant single genes (*L1, L2, L3* and *L4*), which are considered to be alleles at the locus *L*. The different alleles provide resistance towards multiple Tobamovirus species that are classified into four groups (pepper Tobamovirus groups Tm:0-3) on the basis of their differential interactions with the corresponding plant resistanc genes.

The individual Pepper Tobamovirus Groups contain multiple, different viruses.

Note that historically, to facilitate easy communication of resistance claims on Tobamoviruses in pepper, commercial claims by companies were made by using the pest code for TMV (Tm) as a reference to the entire Pepper Tobamovirus Group (instead of claiming each specific individual virus). Now, for pepper the code Tm does not refer specifically to TMV anymore, but to the pepper Tobamovirus Group as a whole.
The same naming rules and guidelines for coding individual viruses, are also applied for the Pepper Tobamovirus Group codes.

Pepper mild mottle virus isolates, which overcome the *L4* resistance gene have been reported in Japan (Genda et al., 2007) and Israel (Antigus et al,, 2008). However till now those isolates did not lead to commercial damage.

	Pepper Tobamovirus Group	**Tm:0**	**Tm:1**	**Tm:2**	**Tm:3**
	ISF Code and races →	TMV ToMV BPMoV	TMGMV PaMMV	PMMoV: 1.2	PMMoV: 1.2.3
Differential hosts	**Gene**				
Lamu, Early Calwonder	*L0*	S	S	S	S
Tisana, Yolo Wonder	*L1*	HR	S	S	S
Tabasco	*L2*	HR	HR	S	S
Solario F1, Novi 3, PI159236	*L3*	HR	HR	HR	S
Tom4, PI260429	*L4*	HR	HR	HR	HR

Annex 3: CPVO tomato protocol for resistance biotest to ToMV (CPVO-TP/044/5)

Ad. 59: Resistance to *Tomato mosaic virus* - Strain 0 (ToMV: 0)
Ad. 60: Resistance to *Tomato mosaic virus* - Strain 1 (ToMV: 1)
Ad. 61: Resistance to *Tomato mosaic virus* - Strain 2 (ToMV: 2)

Resistance to strain 0, 1 and 2 to be tested in a bio-assay (method i) and/or in a DNA marker test (method ii), if appropriate.

(i) Bio-assay

1.	Pathogen	*Tomato mosaic virus*
3.	Host species	*Solanum lycopersicum*
4.	Source of inoculum	Naktuinbouw[15] (NL) or GEVES[16] (FR) or INIA - CSIC[17] (ES, strain 0)
5.	Isolate	Strain 0, (e.g. isolate INRA Avignon 6-5-1-1), strain 1 and strain 2
6.	Establishment isolate identity	genetically defined tomato standards Mobaci (Tm1), Moperou (Tm2), Momor (Tm2^2) Use diffential varieties, see ISF website: https:// www.woldseed.org
7.	Establishment pathogenicity	on susceptible plant
8.	Multiplication inoculum	
8.1	Multiplication medium	living plant
8.2	Multiplication variety	e.g. Moneymaker, Marmande
8.7	Check of harvested inoculum	option: on *Nicotiana tabacum* "Xanthi", check lesions after 2 days
8.8	Shelf life/viability inoculum	fresh>1 day, desiccated>1year
9.	Format of the test	
9.1	Number of plants per genotype	at least 20 plants
9.3	Control varieties	
	Susceptible	Marmande, Monalbo, Moneymaker
	Resistant to ToMV: 0 and 2	Mobaci
	Resistant to ToMV: 0 and 1	Moperou
	Resistant to ToMV: 0, 1 and 2	"Monalbo x Momor" (with necrosis), Gourmet, Mocimor, Momor
9.4	Test design	blank treatment with PBS and carborundum or similar buffer
9.5	Test facility	glasshouse or climate room
9.6	Temperature	24 to 26°C
9.7	Light	12 hours or longer
9.8	Season	symptoms are more pronounced in summer
10.	Inoculation	
10.1	Preparation inoculum	1 g leaf with symptoms with 10 ml PBS or similar buffer Homogenize, add carborundum to buffer (1 g/30 ml)
10.4	Inoculation method	gentle rubbing
10.6	Second observation	cotyledons or 2 leaves
10.7	Final observations	11-21 days after inoculation
11.	Observations	
11.1	Method	visual
11.2	Observation scale	symptoms of susceptibility: mosaic in top, leaf malformation symptoms of resistance (based on hypersensitivity): local necrosis, top necrosis, systemic necrosis
11.3	Validation of test	Evaluation of variety resistance should be calibrated with results of resistant and susceptible controls Remark: in some heterozygous varieties a variable proportion of plants may have severe systemic necrosis or some necrotic spots while the other plants have no symptoms. This proportion may vary between experiments.
12.	Interpretation of data in terms of UPOV characteristic states	absent [1] symptoms of susceptibility present [9] no symptoms, or symptoms of hypersensitive resistance
13.	Critical control points	Temperature and light may influence the development of necrosis. More light means more necrosis. At temperatures above 26°C the resistance may break down. Resistant heterozygous varieties may have symptomless plants and plants with severe necrosis; in spite of apparent segregation the sample may be evaluated as uniform for resistance. Remark: Strain INRA Avignon 6-5-1-1 is recommended for ToMV: 0. This strain causes a striking yellow Aucuba mosaic.

Annex 4: CPVO pepper protocol for resistance biotest to TMV (CPVO-TP/076/3)

Ad. 54: Resistance to Tobamovirus - Tobacco mosaic virus- Group 0 (TMV: 0)

1.	Pathogen	Tobamovirus (the genus containing *Tobacco mosaic virus* (TMV), and *Pepper mild mottle virus* (PMMoV))
2.	Quarantine status	No
3.	Host species	Sweet pepper, hot pepper, paprika and chili – *Capsicum annuum* L.
4.	Source of inoculum	GEVES[1] (FR), Naktuinbouw[2] (NL) or INIA - CSIC[3] (SP)
5.	Isolate	- *Tobacco mosaic virus* group 0 (TMV: 0) strain Vi-6 - *Pepper mild mottle virus* group 2 (PMMoV: 1.2) strain nt203 - *Pepper mild mottle virus* group 3 (PMMoV: 1.2.3) strain Eve The test protocols have been validated in a CPVO co-funded project[4] with these 3 isolates/races
6.	Establishment isolate identity	genetically defined pepper differentials (ref. ISF site Feb. 2020: http://www.worldseed.org/isf/differential_hosts.html)

	Pepper Tobamovirus Group	0	1	2	3
	ISF Code →	TMV: 0,1,2 ToMV: 0,1,2 BPMoV	TMGMV PaMMV	PMMoV: 1.2	PMMoV: 1.2.3
Differential hosts	**Gene**				
Lamu, Early Calwonder	-	S	S	S	S
Tisana, Yolo Wonder	*L1*	HR	S	S	S
Tabasco	*L2*	HR	HR	S	S
Solario F1, Novi 3, PI159236	*L3*	HR	HR	HR	S
Tom4, PI260429	*L4*	HR	HR	HR	HR

S = susceptible; HR = highly resistant;
TMV= *Tobacco mosaic virus*; ToMV= *Tomato mosaic virus*;
PMMoV= *Pepper mild mottle virus;* TMGMV= *Tobacco mild green mosaic virus*;
BPMoV= *Bell pepper mottle virus*; PaMMV= *Paprika mild mottle virus*

7.	Establishment pathogenicity	Test on susceptible plants
8.	Multiplication inoculum	
8.1	Multiplication medium	Regeneration of the virus of plant material before inoculum preparation.
8.2	Multiplication variety	On susceptible pepper variety, Tobamovirus groups may be multiplied on varieties which are selective for each particular group. For TMV, because tomato and tobacco *Nicotiana tabacum* cv. Samsun have large leaves and can produce a lot of inoculum, they are recommended for the multiplication of TMV: 0.
8.3	Plant stage at inoculation	see 10.3
8.4	Inoculation medium	see 10.1
8.5	Inoculation method	see 10.4
8.6	Harvest of inoculum	Symptomatic fresh leaves
8.7	Check of harvested inoculum	option: on young leaves of *Nicotiana tabacum* "Xanthi", check for local lesions after 5-7 days at 20-25°C.
8.8	Shelf life/viability inoculum	fresh > 1 day in fridge, desiccated > 1 year in fridge, or juice > 1 year in freezer at - 20°C.
9.	Format of the test	
9.1	Number of plants per genotype	at least 20 plants

9.2	Number of replicates	-
9.3	Control varieties	TMV: 0: - Susceptible controls: Lamu, Pepita, Piquillo - Resistant controls: Fehérözön, Yolo Wonder PMMoV: 1.2: - Susceptible controls: Fehérözön, Lamu, Yolo Wonder - Resistant controls: Ferrari, Novi 3 PMMoV: 1.2.3: - Susceptible controls: Ferrari, Yolo Wonder - Resistant controls: Friendly, Tom 4 For PMMoV: 1.2.3, it is advised to choose Ferrari as susceptible control because it is resistant to PMMoV: 1.2 or to add the differentials in tests to confirm the group.
9.4	Test design	add non-inoculated plants
9.5	Test facility	Climate room or greenhouse
9.6	Temperature	20-25°C
9.7	Light	12 hours or longer
9.8	Season	-
9.9	Special measures	-
10.	Inoculation	
10.1	Preparation inoculum	1 g leaf with symptoms with 10 mL PBS or similar buffer or dilution of juice in water. Homogenize, add carborundum to buffer
10.2	Quantification inoculum	-
10.3	Plant stage at inoculation	TMV: 0, cotyledons to first leaf stage PMMoV: 1.2 and PMMoV: 1.2.3, cotyledon stage
10.4	Inoculation method	rubbing with the virus suspension
10.5	First observation	TMV:0: 4-7 days post-inoculation for observation of local necrosis. PMMoV: 1.2 and PMMoV: 1.2.3: 4-7 days post-inoculation for observation of local necrotic lesions which can lead to cotyledon drop. After this date these necrosis can hardly be seen on fallen cotyledons
10.6	Second observation	TMV: 0: two weeks post-inoculation for observation of symptoms of susceptibility. PMMoV: 1.2 and PMMoV: 1.2.3: two weeks post-inoculation for observation of symptoms of susceptibility.
10.7	Final observations	TMV: 0: three weeks post-inoculation. PMMoV: 1.2 and PMMoV: 1.2.3: three weeks post-inoculation. For TMV:0, PMMoV: 1.2 and PMMoV: 1.2.3, two of these three observations may be sufficient; the third notation is optional for observation of evolution of symptoms (depending on symptoms on controls or heterogeneous behaviour)
11.	Observations	
11.1	Method	Visual
11.2	Observation scale	TMV: 0: - Susceptibility: mosaic (Aucuba in case of Aucuba strain as Vi-6), growth reduction, death of plants. - Resistance: local necrotic lesions which can lead to leave drop, systemic necrosis, vein necrosis, stem necrosis. PMMoV: 1.2 and PMMoV: 1.2.3: - Susceptibility: mosaic (green), growth reduction. - Resistance: local necrotic lesions which can lead to cotyledon drop, systemic necrosis
11.3	Validation of test	Evaluation of variety resistance should be calibrated with results of resistant and susceptible controls

Annex 5: Proposed differential set for tomato

International Seed Federation
Seed is Life

Nyon, Switzerland
May 2025

DIFFERENTIAL SET

TOMATO MOTTLE MOSAIC VIRUS (ToMMV) – **Tomato**

Differentials	ISF Code and races Gene (s)	ToMMV
Monalbo*, Marmande* Early Pak 7*	-	S
Mobaci*	*Tm*	S
Moperou 161*	*Tm2*	HR
Momor*, Geneva 80, Gourmet	$Tm2^2$	HR

S = Susceptible; HR= High resistant
*** differential hosts and isolates that are used by the seed sector.**

You can find further information on this definitions in the following ISF document https://worldseed.org/document/definitions-of-the-terminology-plants-pests-v-o-seed-industry-2022/

All isolates and differentials are used by the industry

References

Ambros S. et al. (2017). Molecular and biological characterization of an isolate of Tomato mottle mosaic virus (ToMMV) infecting tomato and other experimental hosts in eastern Spain. Eur J Plant Pathol., DOI 10.1007/s10658-017-1180-2

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Tettey C. K. et al, (2023). The role of different innate and environmental factors in Tm-22-mediated resistance to tomato mottle mosaic virus. Phytopathology Research, Volume 5, Issue 8.

Annex 6: Proposed differential set for pepper

International Seed Federation
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Nyon, Switzerland
May 2025

Differential Set

Tobamoviruses (Tobacco mosaic virus (TMV), Tomato mosaic virus (ToMV), Tomato mottle mosaic virus (ToMMV)Tobacco mild green mosaic virus (TMGMV), Paprika mild mottle virus (PaMMV), Pepper mild mottle virus (PMMoV) and Bell pepper mottle virus (BPMoV))- Pepper

The genus *Tobamovirus* includes multiple species that are pathogenic on *Capsicum* spp including the type species *Tobacco mosaic virus* (TMV), and the serologically related *Tomato mosaic virus* (ToMV), *Pepper mild mottle virus* (PMMoV) and several other plant viruses.
The nomenclature of Tobamoviruses has been the subject of several revisions in the period between 1980 and 2004. International Committee on Taxonomy of Viruses (ICTV) is the standard reference for virus taxonomy. More information can be found in the ICTV master species list https://talk.ictvonline.org/

Resistance is governed by four different dominant single genes (*L1, L2, L3* and *L4*), which are considered to be alleles at the locus *L*. The different alleles provide resistance towards multiple Tobamovirus species that are classified into four groups (pepper Tobamovirus groups Tm:0-3) on the basis of their differential interactions with the corresponding plant resistance genes.

The individual Pepper Tobamovirus Groups contain multiple, different viruses.

Note that historically, to facilitate easy communication of resistance claims on Tobamoviruses in pepper, commercial claims by companies were made by using the pest code for TMV (Tm) as a reference to the entire Pepper Tobamovirus Group (instead of claiming each specific individual virus). Now, for pepper the code Tm does not refer specifically to TMV anymore, but to the pepper Tobamovirus Group as a whole.
The same naming rules and guidelines for coding individual viruses, are also applied for the Pepper Tobamovirus Group codes.

Pepper mild mottle virus isolates, which overcome the *L4* resistance gene have been reported in Japan (Genda et al., 2007) and Israel (Antigus et al., 2008). However till now those isolates did not lead to commercial damage.

	Pepper Tobamovirus Group	**Tm:0**	**Tm:1**	**Tm:2**	**Tm:3**
	ISF Code and races →	TMV ToMV BPMoV ToMMV	TMGMV PaMMV	PMMoV: 1.2	PMMoV: 1.2.3
Differential hosts	**Gene**				
Lamu, Early Calwonder	*L0*	S	S	S	S
Tsiana, Yolo Wonder	*L1*	HR	S	S	S
Tabasco (*C. frutescens*)	*L2*	HR	HR	S	S
Solario F1, Novi 3, PI159236 (*C. chinense*)	*L3*	HR	HR	HR	S
Tom4, CAPMVR, PI260429 (*C. chacoense*)	*L4*	HR	HR	HR	HR

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