Development of Differential Hosts to Identify Commercially Relevant Races of Melon *Podosphaera xanthii* Against Which Vegetable Seed Companies Make Claims of Resistance

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Introduction

Cucurbit powdery mildew (CPM) affects the yield and quality of melon worldwide. Races of *Podosphaera xanthii* (Px) and *Golovinomyces cichoracearum* induce identical symptoms of this disease (Pitrat and Bescombes 2008). There are more than 30 reported sources of resistance in melon to the more than 20 known races of Px (Alvarez et al. 2000, Bertrand 2002, McCreight et al. 2012) and these sources can vary in their responses to commonly occurring races of this pathogen (McCreight 2006). Vegetable seed companies are using these sources of resistance to develop commercial melon varieties with resistance to Px. The International Seed Federation Disease Resistance Terminology Working Group (ISF DRT WG) aims to facilitate the consistent naming of plant pathogen races and strains (Vincent et al. 2019) and in 2017 began discussions on how to support and validate the melon CPM resistance claims.

In June 2018, the ISF DRT WG met with CPM experts to discuss melon-relevant Px races and known melon host differentials that can identify and differentiate races of CPM (Lebeda et al. 2016). The aim of the ISF DRT WG was to build on presented information to develop a manageable subset of differentiating melon hosts, assemble commercially relevant Px races and develop protocols that would lend themselves to routine disease resistance testing in order to support commercial claims of resistance. A more detailed evaluation of these differential responses could facilitate development of a core group of differentiating melon hosts with a focus on major resistance genes. This initial study is a crucial step towards understanding similarities and differences between races of Px on a global scale.

Materials and Methods

A comparative ring test was organized by Sandrine Houdault, of GEVES. Fourteen laboratories based in the European Union (EU) and United States (US) participated. Candidate Px isolates were selected based upon data presented by CPM experts during the June 2018 meeting. Characterized isolates had been collected from commercial melon growing areas in the EU and US, were increased and stored for use in the ring test. Isolates of US races SD and Uber were sent to Sandrine for distribution to EU partners. US partners were not able to import and test the EU isolates and instead exchanged local isolates with each other. Candidate melon differentials were also selected based on data presented by CPM experts during the June 2018 meeting: presence of major resistance gene(s), availability, ability to increase seeds, unique responses to Px races, capacity to differentiate races and consistent results between labs. Tested candidate hosts and isolates are included in Table 1. Seeds and isolates were issued a unique code and distributed to all partners in Fall 2019. A total of 25 isolates and 15 candidate differentials were tested. Each isolate was tested by two labs. All partners used the same inoculation protocol and disease rating scale based upon an established CPVO protocol (https://cpvo.europa.eu/sites/default/files/documents/cucumis_melo_2.1.pdf). Melon seedlings were sown in a greenhouse or a growth room and inoculated at the 4-leaf stage by direct deposit of conidia from infected leaves. Twelve plants per candidate host were tested. Inoculated plants were incubated under 14 h, 20°C day and 10 h, 24°C night conditions. Evaluations began when sporulation developed on the susceptible control (approximately 8 to 14 days post-inoculation). A 1-9 rating scale was used to evaluate disease severity (Fig. 1) and interpret the level of resistance. Data were analyzed using a weighted mean with visual assessments of the extent of symptom development.

Results and Discussion

The candidate differentials generally responded as expected in this test, but there were exceptions as variations from expected variety responses to specific races of Px were still observed in these tests. RIL 1 and RIL 4 were derived from the same source, yet differences were observed in responses to the tested Px races. PI 313970 is reported to be highly resistant to all tested races of Px (McCreight and Coffey 2011), yet intermediate resistant responses were observed in this host. Unexpected responses were difficult to interpret for Px isolates Mel 2381-18-27, Mon 19-04, Matref Px: 3-5 and D SRY 18-0105-1. Low sporulation was observed on 'PMR 5' by the Matref Px: 3 isolate whereas this line usually develops necrosis. Three isolates were dropped due to unreadable responses and 22 isolates were selected for a second ring test. The selected candidate differentials and isolates showed a range of reactions from susceptible and virulent to resistant and avirulent, respectively, and represent the diversity of commercially relevant Px isolates in the main melon growing areas.

Variation in the responses have been reported and can be attributed to genetic variation for virulence in the pathogen (Alvarez et al. 2000, McCreight 2006). Slight differences in rating evaluation and resistance interpretation can also contribute to observed variation in response to inoculation. In comparative testing, unaccounted differences in testing environment introduces other variables that can result in differences in host responses. This comparative ring test will be repeated in early 2021.

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Literature Cited

1. Alvarez, J. M., M. L. Gomez-Guillamon, N. A. Torres, I. Canovas, E. Floris. 2000. Virulence differences between two Spanish isolates of *Sphaerotheca fuliginea* race 2 on melon. Acta Hort. 510:67-69. https://doi.org/10.17660/ActaHortic.2000.510.10
2. Bertrand, F. 2002. AR Hale's Best Jumbo, a new differential melon variety for *Sphaerotheca fuliginea* races in leaf disk test, p. 234-23. In: D.N. Maynard (ed.). Cucurbitaceae 2002 ASHS Press, Alexandria, Va.
3. Lebeda, A., E. Kristkova, B. Sedlakova, J.D. McCreight. 2016. Initiative for international cooperation of researchers and breeders related to determination and denomination of cucurbit powdery mildew races, p. 148-152. In: E.U. Kozik and H.S. Paris (eds.) Proceedings of the XIth EUCARPIA Meeting on Genetics and Breeding of Cucurbitaceae, Warsaw, Poland. DOI 10.5281/zenodo.1255670
4. McCreight, J. D., M. D. Coffey. 2011. Inheritance of resistance in melon PI 313970 to cucurbit powdery mildew incited by *Podosphaera xanthii* race S. HortScience 46:838-840. https://doi.org/10.21273/HORTSCI.46.6.838
5. McCreight, J.D., M.D. Coffey, B. Sedlakova, and A. Lebeda. 2012. Cucurbit powdery mildew of melon incited by *Podosphaera xanthii*: Global and western U.S. perspectives, p. 181–189. In: N. Sari, I. Solmaz, and V. Aras (eds.). Cucurbitaceae 2012, Proceedings of the Xth EUCARPIA Meeting on Genetics and Breeding of Cucurbitaceae, Antalya (Turkey), October 15-18th, 2012. https://zenodo.org/record/1255624#.YFNPkC2cZQI
6. McCreight, J. D. 2006. Melon-powdery mildew interactions reveal variation in melon cultigens and *Podosphaera xanthii* races I and 2 in melon PI 313970. J. Amer. Soc. Hort. Sci. 131:59-65 https://doi.org/10.21273/JASHS.131.1.59
7. Pitrat, M., D. Besombes. 2008. Inheritance of *Podosphaera xanthii* resistance in melon line '90625', p. 135-142. In: M. Pitrat (ed.) Proceedings of the IXth EUCARPIA Meeting on Genetics and Breeding of Cucurbitaceae. https://toc.library.ethz.ch/objects/pdf/e01_978-2-7380-1251-7_01.pdf
8. Vincent, T., P.T. Himmel, P. Brown, S. Ruthner, V. Grimault. 2019. ISF Guidelines on the nomination of novel plant pest races. Abstr. Phytopathology 109-10-S2.110. https://doi.org/10.1094/PHYTO-109-10-S2.1

Table 1. Summary of results of a ring test of 22 *Podosphaera xanthii* isolates on 15 melon candidate differential lines in 14 laboratories in the European Union and United States; each isolate was tested by two laboratories.

Isolates	Characterized race	Test Code	Vedrantais	Ames 31282	PMR45	WMR29	E disto47	PMR5	Arago	RIL 1 = RIL N°14	Durango	PI482420	PI124112	RIL 4 = RIL N°44	Arum	SVI105	PI313970
RZ_ID470	Px: 3-5	V	S	S	S	S	S	S	S	S	S	S	S	IR	S	IR	IR
Venturia		M	S	S	S	S	S	S	S	IR/S	IR/S	S	S	IR	S	IR	IR
Mon 19-6		T	S	S	S	S	S	S	S	S	S	IR	S	S	IR/R	IR	IR
RZ_ID4578		S	S	S	S	S	S	IR/S	S	IR/S	S	R	S	S	IR/R	IR/R	IR
Mon 18-1	Px: 3-5	X	S	S	S	S	S	IR/S	S	S	S	IR/S	S	IR/S	IR/R	IR/S	IR
RZ_ID873	Px: 3-5	Q	S	S	S	IR/S	IR	S	S	S	S	S	R	S	R	R	R
SRY 18.0109.2		N	S	S	S	IR/S	IR	S	S	S	S	S	IR/R	S	IR/R	IR	IR/R
RZ_ID1330		W	S	S	S	S	S	IR/S	S	S	S	IR/S	R	R	R	R	R
Envero		G	S	S	S	S	S	IR/S	S	IR	IR	S	IR	IR	IR/S	IR/R	IR/R
Uber race	Uber	R	S	S	S	S	S	S	IR	IR/R	IR	IR/R	S	IR/R	R	R	IR
Mel2381-18-27		C	S	S	S	S	S	IR	R/S	S	S	IR/S	IR	IR/S	IR/R	R	IR/R
CM18043		A	S	S	S	S	S	S	IR/S	IR/R	IR/R	IR/R	IR/R	R	R	R	R
Px:5 Matref	Px: 5	Y	S	S	S	S	S	R	IR	S	IR	R	R	IR	R	R	IR
Px: 3-5 Matref	Px: 5	J	S	S	S	S	S	IR	IR/R	R/IR/S	IR/R	IR/R	R	IR/R	R	R	R
Mon19-04	Px: 3-5	E	S	S	S	S	IR	S	IR	IR	IR	IR	R	R	R	R	R
Race 2 US	Px: 2 US	2 US	S	S	IR	IR	S	R	R	R	S	IR	IR	S	R	IR	IR
Px:2 Matref	Px: 2	I	S	S	S	R	R	R	IR/R	IR/R	IR/R	R	R	R	R	R	R
Px:3 Matref	Px: 3	P	S	S	S	R	R	IR	IR	IR	IR	IR/R	R	IR	R	R	R
RZ_ID1296		F	S	S	R	R	R	R	R	S	R	IR/S	R	IR/R	R	R	R
Px:1 Matref	Px: 1	U	S	S	R	R	R	R	R	IR	R	R	R	R	R	R	R
SalGH2018	SD	H	S	R	R	R	IR/R	IR/R	R	R	R	R	IR/R	S	R	R	R
SRY 18-0105-1	Px: 1	D	S	S	IR/R	R	R	R	R	IR/R	R	R	R	R	R	R	R

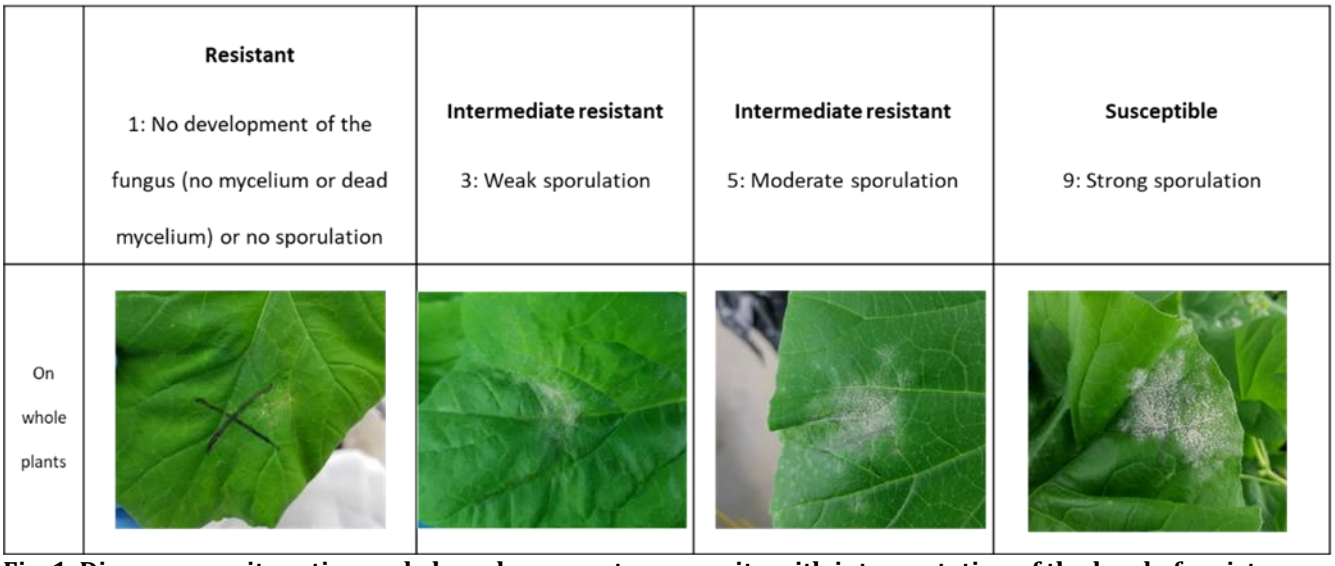

Fig. 1. Disease severity rating scale based on symptom severity with interpretation of the level of resistance