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Behaviour of apricot (*Prunus armeniaca* L.) cultivars in the presence of sharka (plum pox potyvirus): a review

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Abstract – Information concerning the evaluation of apricot resistance to sharka (plum pox potyvirus) has in many cases been published in journals of limited circulation. In an attempt to assess the actual status of this resistance, a global review has been made, including 222 cultivars, 175 of which can be considered as susceptible, 27 as resistant and 20 as cultivars of uncertain classification. Such a doubtful classification could be due to differences in evaluation methods, the isolates used, or to the authenticity of the plant material. The results seem to indicate that the main origin of resistance to sharka could be North American cultivars, although other resistant sources have been found in Central Europe.

Prunus armeniaca L. / apricot / plum pox potyvirus / sharka / resistance

Résumé – **Comportement des cultivars d'abricotier (*Prunus armeniaca* L.) à la sharka (plum pox potyvirus) : une revue.** Les informations concernant l'évaluation du comportement de l'abricotier à la sharka sont fréquemment publiées dans des journaux à faible audience. La présente revue se propose de synthétiser ces informations dispersées : 222 cultivars sont pris en compte, 175 d'entre eux pouvant être considérés comme sensibles, 27 comme résistants et 20 pour lesquels la classification est incertaine. Cette classification douteuse peut être due à des différences dans les méthodes d'évaluation, aux isolats utilisés ou à l'authenticité du matériel végétal. Les résultats semblent indiquer que la principale source de résistance à la sharka aurait pour origine les cultivars nord-américains bien que d'autres sources de résistance ont été trouvées en Europe centrale.

Prunus armeniaca L. / abricotier / plum pox potyvirus / sharka / résistance

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1. Introduction

Sharka, a disease produced by plum pox potyvirus (PPV), is one of the most important limiting factors in apricot cultivation. Described for the first time in Bulgaria at about the time of the First World War [3], it spread throughout Europe [45], North Africa [21], India [50], Chile [2] and, more recently, the USA [9].

Sharka affects most species of the genus *Prunus*, especially apricot, peach and plum trees [31, 36]. It also affects cherries [11, 25] and has been experimentally transmitted to almond [12].

PPV is characterised by its wide genetic variability, although two main isolates have been described in Europe: Dideron (D) and Marcus (M) [10]. Other less widespread isolates have also been described: El Amar (E) [52] and Cherry (SoC) [35].

The use of certified healthy plant material is one of the key elements for orchard protection [30, 37, 43]. In infected areas, the uprooting of diseased trees avoids uncontrolled spreading, but does not guarantee eradication [16] due to non-persistent aphid transmission and the time elapsing between inoculation and the appearance of symptoms. A long term solution must involve the cultivation of resistant cultivars [4, 15, 22, 28, 31].

All cultivars of European origin have been demonstrated as sharka-susceptible in field trials [26, 27, 49], while the first cultivars to be confirmed as resistant came from North America [26, 47]. However, the direct use of these cultivars in Europe has been ruled out since they are generally self-incompatible, produce low-quality fruits and have high chilling requirements. For this reason, European efforts have concentrated on obtaining new resistant cultivars [4, 22, 29, 38], and on providing an objective characterisation of the level of resistance of the cultivars in use.

The transmission of such resistance to the descendants of resistant cultivars such as 'Stark Early Orange' [19, 20] or 'Stella' [6, 14] has also been studied. This transmission of resistance in apricot has been described as an oligogenic characteristic in some cases [18, 19], and, more recently, as a monogenic characteristic [17].

The existent information regarding the susceptibility or resistance of an apricot cultivar to PPV is not easily compiled, since it may be contained in a variety of publications, many of which have a limited readership. Furthermore, the characterisation of cultivar susceptibility is occasionally contradictory because of differences in evaluation conditions, sites, strains and possible discrepancies in the plant material.

The purpose of this study was to provide a synthesis of the information available on the resistance or susceptibility of apricot cultivars to PPV, based on a review of the bibliography, which refers to the evaluation of cultivars in different conditions and using different isolates.

2. Methodology

In order to compare the different information, the following criteria were recorded: i) cultivar: native name of the apricot cultivar studied; ii) origin: country of origin of the cultivar; iii) level of resistance: the classification of cultivar resistance depends on the authors cited as reference [4, 24, 31]. The scheme proposed in this review is classified into three different levels: s: susceptible, cultivars showing symptoms after infection; t: tolerant, cultivars without symptoms after infection, which react positively to the serological ELISA test (+); r: resistant cultivars without symptoms after infection and which test negative to the serological ELISA test (-).

2.1. Evaluation conditions

The evaluation conditions were as follows: f: in the field, in the open air; gh: in the controlled conditions of an insect-proof greenhouse.

2.2. Inoculation

The type of inoculation was as follows: n: natural inoculation (by aphids); c: chip or chip-budding

inoculation (grafting) with a controlled infected source; x: grafting onto a heavily infected adult tree.

2.3. Isolate

The isolates used in a controlled inoculation or strain type present in the area in natural infection conditions were as follows: M: Marcus; D: Dideron; E: El Amar.

2.4. Years

This parameter concerned the number of years studied in the field or the number of vegetative cycles studied in controlled greenhouse or screen-house conditions.

2.5. Leaf symptoms

Most authors use a scale of between 0 (no symptoms) and 3 (maximum expression of symptoms), although some studies refer to a scale of 0–5. We used a scale of 0–3 and converted the data of the latter system to this scale. In some cases, the evaluation was only reported in term of presence (+) or absence (–) of symptoms.

2.6. Fruit symptoms

A similar scale (0–3) to that reported above was used. This scale was used in all the references studied: 0 = absence of symptoms; 1 = slight yellowish ring symptoms; 2 = clear yellow symptoms; 3 = strong symptoms with fruit deformation.

2.7. Detection techniques

The application of different techniques has been mentioned, for example enzyme like immunosorbent assay (ELISA), immuno capture reverse transcriptase polymerase chain reaction (IC-RT-PCR), immunosorbent electron microscopy (ISEM) or tissue printing (TP). The type of reaction is described as positive (+) or negative (–).

2.8. References

The references used were those found in the literature. The information obtained was organised into three different tables as a function of the degree of susceptibility attributed to the different cultivars by each author.

3. Results and discussion

This survey of apricot cultivar susceptibility indicated the existence of 3 categories: susceptible, resistant, and cultivars that were classified differently by different authors. According to this classification, most cultivars (175) were considered to be susceptible (Tab. I); only 27 were described as completely resistant (Tab. II); and 20 were of uncertain classification (Tab. III).

Most of the registered data was from 3 different origins:

- Natural infection in the field, with M strains in Central European countries and Greece [8, 27, 47, 48, 51], D strains in Spain [7, 44] and M and D strains in France [6, 18].

- Controlled infection in the field in Yugoslavia [42], the Czech Republic [38–40, 46] and in Greece [29] with M strains.

- Controlled infection in insect-proof greenhouse or screen-house with M and D strains in France [4, 5, 18–20], and D strains in Germany [24] and in Spain [32–34].

As regards the number of years the studies lasted, those carried out in the field in natural infection conditions or by grafting onto diseased trees lasted between one and ten years, while the assays carried out in sealed greenhouses and involving artificial inoculation were considerably shorter, lasting one or two years only (two or four growth cycles). It seems that the evaluation of resistance in controlled conditions (controlled inoculation) is a more rapid undertaking than in conditions of natural infection (by aphids), although the former, it must be admitted, is also more laborious. Grafting onto infected trees in the field is the more effective and easier evaluation method.

Table I. Apricot cultivars generally described as susceptible to plum pox potyvirus.

Cultivar	Origin	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference
Amabile Vecchioni	Italy	gh	C	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Amal	Tunisia	f	N	M	4	2.4	2.8		Karayiannis, 1989
Ambrosia	Germany	f	N	M	1	3.0	2.0		Audergon <i>et al.</i> , 1995b
Aprikoz	Turkey	f	N	M	4	3.0	2.2		Elibüyük and Erdiller, 1995
Arrogantes	Spain	f	N	D	2	0.5			Rodríguez <i>et al.</i> , 1995
Avikour	France	gh	C	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Avignel	France	f	N	M	1	+ ⁽¹⁾			Audergon <i>et al.</i> , 1995b
		gh	C	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Bademovidna	Yugoslavia	f	N	M	1	1.0	3.0		Audergon <i>et al.</i> , 1995b
Balady	Syria	f	N	E	3	+ ⁽¹⁾			Aboul-Ela <i>et al.</i> , 1999
Banaesa	Yugoslavia	gh	C	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Baracca	Italy	f	N	M	4	2.3	2.8		Karayiannis, 1989
Bebecou	Greece	gh	C	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1988
		gh	C	D	2	2.5			Audergon <i>et al.</i> , 1994
		gh	c	D	2	2.5			Audergon <i>et al.</i> , 1995a
		gh	c	D	1	+ ⁽¹⁾		+ ⁽⁵⁾	Dicenta and Audergon, 1995
		f	n	M	4	2.3	2.5		Karayiannis, 1989
		f	n	M	1	3.0	2.0		Audergon <i>et al.</i> , 1995b
		f	n	M	5	2.3	2.5		Audergon <i>et al.</i> , 1995a
Bergeron	France	f	n	M	4	2.3	2.5		Karayiannis, 1989
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1988
		f	c	M	5	3.0			Sedlakova and Gallo, 1994
Best of Hungary	Romania	f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Blanco de Ceutí	Spain	f	n	M	1	3.0	2.0		Audergon <i>et al.</i> , 1995b
Blenheim	USA	f	n	M	4	2.2	2.8		Karayiannis, 1989
Blentyl	USA	f	n	M	4	1.0	3.0		Balan and Stoian, 1995
Boccucia	Italy	f	n	M	4	2.4	2.8		Karayiannis, 1989
		f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Breda	Germany	f	n	M	4	2.0	0.0		Karayiannis, 1989
Búlida	Spain	gh	c	D	2	0.6		+ ⁽²⁾	Martínez-Gómez and Dicenta, 2000
		f	n	M	4	2.3	2.8		Karayiannis, 1989
		f	n	M	1	3.0	1.0		Audergon <i>et al.</i> , 1995b
Cafona	Italy	f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Caldesi	Italy	f	n	M	1	+ ⁽¹⁾			Audergon <i>et al.</i> , 1995b
Canette	Italy	f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Canino	Spain	f	c	D	1	3.0	1.0		Avinent <i>et al.</i> , 1993
		f	n	D	2	2.3	1.8		Rodríguez <i>et al.</i> , 1995
		gh	c	D	2	1.4		- ⁽²⁾	Martínez-Gómez and Dicenta, 2000
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1988
		f	n	M	4	2.5	3.0		Karayiannis, 1989
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1991
		f	n	M	1	3.0	3.0		Audergon <i>et al.</i> , 1995b
		f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Cañahueca	Spain	f	n	D	2	1.0	2.1		Rodríguez <i>et al.</i> , 1995
Carrascal	Spain	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Carrichosa	Spain	f	n	D	2	0.1	0.1		Rodríguez <i>et al.</i> , 1995
Castlebrite	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1	+ ⁽¹⁾			Audergon <i>et al.</i> , 1995b
Cegledi	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992

Table I. (continued).

Cultivar	Origin	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference
Cöloglu	Turkey	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	1	+ ⁽¹⁾			Audergon <i>et al</i> , 1995b
		f	n	M	4	3.0	2.2		Elibüyük and Erdiller, 1995
Colomer	France	gh	c	D	2	2.8			Audergon <i>et al</i> , 1994
		gh	c	D	2	3			Audergon <i>et al</i> , 1995a
		gh	c	D	1	+ ⁽¹⁾		+ ⁽⁵⁾	Dicenta and Audergon, 1995
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		f	n	M	1	2.2	3.0		Audergon <i>et al</i> , 1995a
Colorao	Spain	f	n	D	2	1.6	1.4		Rodríguez <i>et al</i> , 1995
Colorao Antón	Spain	f	n	D	2	1.9	2.1		Rodríguez <i>et al</i> , 1995
Comandor	Romania	f	n	M	4	1.0	1.2		Balan and Stoian, 1995
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
Competna	?	f	n	M	1	3.0	1.0		Audergon <i>et al</i> , 1995b
Corbató	Spain	f	c	D	1	3.0	1.0		Avinent <i>et al</i> , 1993
		f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
Cortos Archena	Spain	f	n	D	2	0.1			Rodríguez <i>et al</i> , 1995
Currot	Spain	f	c	D	1	3.0	3.0		Avinent <i>et al</i> , 1993
		f	n	D	2	2.4	2.9		Rodríguez <i>et al</i> , 1995
		gh	c	D	2	1.0		+ ⁽²⁾	Martínez-Gómez and Dicenta, 2000
Chirivello	Italy	f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
		f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
		f	x	M	1	2.0		+ ⁽²⁾⁽³⁾	Polák <i>et al</i> , 1995b
Da Ju Bada	China	f	n	M	4	1.5	1.5		Balan and Stoian, 1995
		f	x	M	4	2.0	2.0	+ ⁽²⁾⁽⁴⁾	Polák <i>et al</i> , 1997
Dacia	Romania	f	n	M	4	1.5	1.5		Balan and Stoian, 1995
Damasco	Spain	f	n	D	2	0.2	1.7		Rodríguez <i>et al</i> , 1995
De Olanda	France	f	n	M	4	3.0	1.0		Balan and Stoian, 1995
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
Desfarges	?	f	n	M	1	+ ⁽¹⁾			Audergon <i>et al</i> , 1995b
Diamantopoulou	Greece	f	n	M	4	2.7	3.0		Karayiannis, 1989
Dioses	Spain	f	n	D	2	0.0	1.0		Rodríguez <i>et al</i> , 1995
Dobruganska	Yugoslavia	f	n	M	4	2.2	3.0		Karayiannis, 1989
Don Gaetano	Italy	f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Dryanovska	?	f	n	M	4	2.3	2.8		Karayiannis, 1989
Early Bee	USA	f	n	M	4	3.0	2.2		Balan and Stoian, 1995
Early Divinity	USA	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
Early Golden	USA	f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Erevani	Italy	f	n	M	4	2.7	1.3		Karayiannis, 1989
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
Eugenios	Spain	f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
		f	n	D	2	0.7	1.2		Rodríguez <i>et al</i> , 1995
Favorit	Romania	f	n	M	1	3.0	1.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	3.0	1.8		Balan and Stoian, 1995
Fenómeno	Spain	f	n	D	2	+ ⁽¹⁾	1.9		Rodríguez <i>et al</i> , 1995
Festivalna	Italy	f	n	M	4	2.2	0.7		Karayiannis, 1989
Gergana	?	f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
Ginesta	Spain	f	c	D	1	3.0	2.0		Avinent <i>et al</i> , 1993
		f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
Gitano	Spain	f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
Grossa Giardino	Italy	f	n	M	4	2.3	1.8		Karayiannis, 1989

Table I. (continued).

Cultivar	Origin	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference
Helena Roussillon	France	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1988
Hacihaliloglu	Turkey	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	4	3.0	2.2		Elibüyük and Erdiller, 1995
Hamawey	Egypt	f	n	E	3	+ ⁽¹⁾		+ ⁽²⁾	Aboul-Ela <i>et al.</i> , 1999
Harogem	Canada	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	4	2.1	3.0		Karayiannis, 1989
Harglow	Canada	f	n	M	1	+ ⁽¹⁾			Audergon <i>et al.</i> , 1995b
Hargrand	Canada	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1	+ ⁽¹⁾			Audergon <i>et al.</i> , 1995b
Hasanbey	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1	+ ⁽¹⁾			Audergon <i>et al.</i> , 1995b
Hasiotico	?	f	n	M	1	3.0	2.0		Audergon <i>et al.</i> , 1995b
Hatif Colomer	France	f	n	M	4	2.2	3.0		Karayiannis, 1989
Hunter	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Hyperproimo	Greece	f	n	M	4	2.7	3.0		Karayiannis, 1989
Imrahor	Iran	f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Irwin	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1988
		gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1991
Jubilena	Yugoslavia	f	n	M	4	2.5	0.3		Karayiannis, 1989
Karakabey	Yugoslavia	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1	3.0	2.0		Audergon <i>et al.</i> , 1995b
Kishinevska	Yugoslavia	f	n	M	4	2.8	1.3		Karayiannis, 1989
		f	n	M	1	3.0	3.0		Audergon <i>et al.</i> , 1995b
Kisineuskij	Yugoslavia	f	c	M	5	3.0			Sedlakova and Gallo, 1994
Kostujenska	Yugoslavia	f	n	M	4	2.3	1.7		Karayiannis, 1989
Krymskij	Yugoslavia	f	x	M	1	2.0		+ ⁽²⁾⁽³⁾	Polák <i>et al.</i> , 1995b
		f	x	M	4	3.0	3.0	+ ⁽²⁾	Polák <i>et al.</i> , 1997
Lambertin	France	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Liberato	Spain	f	n	D	2	0.5	2.29		Rodríguez <i>et al.</i> , 1995
Ligeti	Italy	f	c	M	5	3.0			Sedlakova and Gallo, 1997
Litoral	Romania	f	n	M	4	2.5	2.5		Balan and Stoian, 1995
Luizet	France	f	n	M	4	2.5	1.5		Karayiannis, 1989
Madarska	Romania	f	c	M	5	3.0			Sedlakova and Gallo, 1994
		f	n	M	4	2.0	0.5		Karayiannis, 1989
Mai Chua Sin	China	f	x	M	2	2.0		+ ⁽²⁾⁽³⁾	Polák <i>et al.</i> , 1995b
		f	x	M	4	2.0	2.5	+ ⁽²⁾⁽⁴⁾	Polák <i>et al.</i> , 1997
Mala Hierba	Spain	f	n	D	2	1.76			Rodríguez <i>et al.</i> , 1995
Mandula	Romania	f	n	M		3.0			Tradafirescu and Topor, 1999
Manicot	France	gh	c	D	1	+ ⁽¹⁾		+ ⁽²⁾	Audergon <i>et al.</i> , 1995b
		gh	c	D	1	+ ⁽¹⁾		+ ⁽⁵⁾	Dicenta and Audergon, 1995
Marculesti	Romania	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1	3.0	3.0		Audergon <i>et al.</i> , 1995b
		f	n	M		3.0			Tradafirescu and Topor, 1999
Marraneros	Spain	f	n	D	2	0.1			Rodríguez <i>et al.</i> , 1995
Maxgold	USA	f	n	M	4	3.0	2.8		Balan and Stoian, 1995
Mektep	Iran	f	n	M	4	3.0	2.5		Balan and Stoian, 1995
Mitger	Spain	f	c	D	1	3.0	1.0		Avinent <i>et al.</i> , 1993
		f	n	M	1	3.0	3.0		Audergon <i>et al.</i> , 1995b
Mocodoi	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992

Table I. (continued).

Cultivar	Origin	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference
Modesto	Spain	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
Monaco Bello	Italy	f	n	M	1	+ ⁽¹⁾			Audergon <i>et al</i> , 1995b
Moniquí	Spain	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
Moniquí Fino	Spain	f	n	D	1	3.0	2.0		Audergon <i>et al</i> , 1995b
Moorpark	Australia	f	n	M	4	1.0	2.0		Balan and Stoian, 1995
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> ., 1992
Morocco	Morocco	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
Nagy Korosi	Hungary	f	n	M	4	1.0	1.0		Balan and Stoian, 1995
Neptum	Romania	f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	2.0	3.0		Balan and Stoian, 1995
NJA19	USA	f	n	M	4	3.0	1.5		Balan and Stoian, 1995
NJA55	USA	f	n	M	1	+ ⁽¹⁾			Audergon <i>et al</i> , 1995b
Nonno	Italy	f	n	M	4	1.5	3.0		Karayiannis, 1989
Olimp	Romania	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	1.0	3.0		Balan and Stoian, 1995
Ouardi	Tunisia	f	n	M	4	2.6	2.8		Karayiannis, 1989
Palabras	Spain	f	c	D	1	3.0	2.0		Avinent <i>et al</i> , 1993
		f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
Palau	Spain	f	c	D	1	3.0	2.0		Avinent <i>et al</i> , 1993
		f	n	D	2	0.8	0.4		Rodríguez <i>et al</i> , 1995
Palen	?	f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
Palstein	S. Africa	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1991
Palumella	Italy	f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
Patriarca	Spain	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Paviot	Spain	f	n	M	4	2.2	2.5		Karayiannis, 1989
Pepito	Spain	f	n	D	2	1.6	1.4		Rodríguez <i>et al</i> , 1995
Pepitos Blancos	Spain	f	n	D	2	0.1			Rodríguez <i>et al</i> , 1995
Polonais	France	f	n	M	4	2.3	1.8		Karayiannis, 1989
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1991
Portici	Italy	f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
Precoce Boulbon	France	f	n	M	4	2.3	2.1		Karayiannis, 1989
		f	n	M	4	3.0	2.2		Elibüyük and Erdiller, 1995
Precoce Pugget	France	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	1	+ ⁽¹⁾			Audergon <i>et al</i> , 1995b
Precoce Tirynthos	Greece	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		f	n	M	4	2.5	3.0		Karayiannis, 1989
Precoce Toscana	Italy	gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1991
Precoce Tunisie	Tunisia	f	n	M	4	2.6	3.0		Karayiannis, 1989
Prevette	France	f	n	M	4	3.0	1.0		Balan and Stoian, 1995
Rakowsky	Turkey	f	n	M	4	3.0	2.2		Elibüyük and Erdiller, 1995
Real Fino	Spain	f	n	D	2	0.1			Rodríguez <i>et al</i> , 1995
		gh	c	D	2	1.3		+ ⁽²⁾	Martínez-Gómez and Dicenta, 2000
Reale d'Imola	Italy	f	n	M	2	3.0		+ ⁽²⁾	Tradafirescu and Topor, 1999

Table I. (continued).

Cultivar	Origin	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference
Reales Cortos	Spain	f	n	D	2	1.3	1.9		Rodríguez <i>et al</i> , 1995
Ricordo Buonamico	Italy	f	n	M	4	2.6	2.0		Karayiannis, 1989
Roches	Spain	f	n	D	2	0.8	0.9		Rodríguez <i>et al</i> , 1995
Rojo de Carlet	Spain	f	c	D	1	3.0	1.0		Avinent <i>et al</i> , 1993
		f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
Rouge Rivesaltes	France	f	n	M	4	2.2	3.0		Karayiannis, 1989
Rouge Roussillon	France	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1991
Rouge Sernhac	France	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1991
Rouge Tardif	France	f	n	M	4	2.5	3.0		Karayiannis, 1989
Royal	France	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	4	2.0	3.0		Balan and Stoian, 1995
Sam	Turkey	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	4	3.0	2.2		Elibüyük and Erdiller, 1995
San Castresse	Italy	f	x	M	2	1.0		+ ⁽²⁾ (³)	Polák <i>et al</i> , 1995b
		f	x	M	4	2.0	3.0	+ ⁽²⁾ (⁴)	Polák <i>et al</i> , 1997
San Francesco	Italy	f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
Saturn	Romania	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	3.0	2.0		Balan and Stoian, 1995
Sayeb Beliana	Tunisia	f	n	M	4	2.7	3.0		Karayiannis, 1989
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
Screara	France	gh	c	D	2	2.0			Audergon <i>et al</i> , 1994
		gh	c	D	1	3.0			Audergon <i>et al</i> , 1995a
		gh	c	D	1	+ ⁽¹⁾		+ ⁽⁵⁾	Dicenta and Audergon, 1995
		gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		f	n	M	4	2.5	2.8		Karayiannis, 1989
		gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1991
		f	n	M	1	2.5	2.8		Audergon <i>et al</i> , 1995a
		f	x	M	1	3.0	2.0		Audergon <i>et al</i> , 1995a
		f	n	M		3.0			Tradafirescu and Topor, 1999
Selena	Romania	gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	2.0	2.0		Balan and Stoian, 1995
Septembriska	Yugoslavia	f	n	M	1	3.0	1.0		Audergon <i>et al</i> , 1995b
Sirena	Romania	gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	3.0	1.0		Balan and Stoian, 1995
Skaha	Canada	f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	2.0	1.5		Balan and Stoian, 1995
Steam Rosie	Romania	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	1	+ ⁽¹⁾			Audergon <i>et al</i> , 1995b
Sulina	Romania	f	n	M	1	3.0	3.0		Audergon <i>et al</i> , 1995b
		f	n	M	4	1.2	3.0		Balan and Stoian, 1995
Sulmona	Romania	gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		f	n	M	4	3.0	3.0		Balan and Stoian, 1995
		f	n	M	1	3.0	2.0		Audergon <i>et al</i> , 1995b
Sungold	USA	f	n	M	4	1.0	3.0		Balan and Stoian, 1995

Table I. (continued).

Cultivar	Origin	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference
Szegadti Mamut	Hungary	f	n	M	4	1.0	3.0		Balan and Stoian, 1995
Tadeo	Spain	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	c	D	1	3.0	1.0		Avinent <i>et al.</i> , 1993
		f	n	M	1	3.0	2.0		Audergon <i>et al.</i> , 1995b
Talda	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Tardif Bordaneil	France	f	n	M	4	2.2	2.5		Karayiannis, 1989
Timpurii Chisinou	Moldavia	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Timpurii Bancasa	Romania	f	n	M	4	2.3	1.0		Balan and Stoian, 1995
Tiryntos	Greece	gh	c	D	2	2.0			Audergon <i>et al.</i> , 1994
		gh	c	D	1	2.5			Audergon <i>et al.</i> , 1995a
		f	n	M	1	3.0	3.0		Audergon <i>et al.</i> , 1995b
		f	n	M	2	3.0	3.0		Audergon <i>et al.</i> , 1995a
		f	x	M	2	3.0	3.0		Audergon <i>et al.</i> , 1995a
Tokaloglu	Turkey	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1	3.0	3.0		Audergon <i>et al.</i> , 1995b
		f	n	M	4	3.0	2.2		Elibüyük and Erdiller, 1995
Trandafiniu		f	n	M	1	+ ⁽¹⁾			Audergon <i>et al.</i> , 1995b
Trevatt	?	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al.</i> , 1992
Trujillos	Spain	f	n	D	2	0.2	1.4		Rodríguez <i>et al.</i> , 1995
Ugarska	Yugoslavia	f	n	M	1	3.0	2.0		Audergon <i>et al.</i> , 1995b
Uleanos	Spain	f	n	D	2	0.6			Rodríguez <i>et al.</i> , 1995
Umberto	Romania	f	n	M	4	1.0	1.0		Balan and Stoian, 1995
Velázquez	Spain	f	n	D	2	0.4	2.5		Rodríguez <i>et al.</i> , 1995
Velkopaulovicha	Czech Rep.	f	c	M	5	3.0			Sedlakova and Gallo, 1994
		f	x	M	4	3.0	2.5	+ ⁽²⁾ (⁴)	Polák <i>et al.</i> , 1997
Venus	Romania	f	n	M	1	3.0	1.0		Audergon <i>et al.</i> , 1995b
		f	n	M	4	2.0	3.0		Balan and Stoian, 1995
Vesna	Czech Rep.	f	c	M	5	3.0			Sedlakova and Gallo, 1994
Vespar	Czech Rep.	f	c	M	5	3.0			Sedlakova and Gallo, 1994
Vestar	Czech Rep.	f	x	M	1	2.0		+ ⁽²⁾ (³)	Polák <i>et al.</i> , 1995b
		f	x	M	4	2.0	3.0	+ ⁽²⁾ (⁴)	Polák <i>et al.</i> , 1997
Wenatchee	USA	f	n	M	4	3.0	3.0		Balan and Stoian, 1995
Worley's Peach	USA	f	n	M	4	2.0	3.0		Balan and Stoian, 1995
Zhang Gong Juan	China	f	x	M	1	2.0		+ ⁽²⁾ (³)	Polák <i>et al.</i> , 1995b

(?): unknown origin.

Eval: evaluation conditions (f = field, gh = greenhouse).

Inoc: inoculation method (n = natural, c = chip, x = grafting onto an infected tree).

Isol: isolate used (M = Marcus, D = Dideron).

Years: years or cycles of study.

Le s: symptoms in leaves (0–3), ⁽¹⁾ Scale not specified.

Fr s: symptoms in fruits (0–3), ⁽¹⁾ Scale not specified.

D t: detection technique, ⁽²⁾ ELISA (+ or –), ⁽³⁾ ISEM (+ or –), ⁽⁴⁾ IC-RT-PCR (+ or –), ⁽⁵⁾ TP (+ or –).

Table II. Apricot cultivars described as resistant to plum pox potyvirus.

Cultivar	Origin	Eval	Inoc	Isol	Year	D t	Reference
Alfred	USA	f	n	M	1		Rankovic <i>et al.</i> , 1999
Avilara	France	gh	c	D	2	– ⁽¹⁾	Martínez-Gómez and Dicenta, 2000
		f	n	M	1		Audergon <i>et al.</i> , 1995b
		f	n	M	5	– ⁽¹⁾	Karayiannis <i>et al.</i> , 1999
Brevira	Germany	gh	c	D	2	– ⁽¹⁾	Fuchs <i>et al.</i> , 1998
Cais Olanda	?	f	n	M	2		Tradafiresfu and Topor, 1997
Ceccoona	Italy	f	n	M	4		Balan and Stoian, 1995
Framingdale	USA	f	n	M	1		Rankovic <i>et al.</i> , 1999
Harlayne	Canada	gh	c	D	2	– ⁽¹⁾	Fuchs <i>et al.</i> , 1998
		gh	c	M	3	– ⁽¹⁾	Dosba <i>et al.</i> , 1992
		f	x	M	2	– ⁽¹⁾	Karayiannis and Mainou, 1994
		f	n	M	1		Audergon <i>et al.</i> , 1995b
		f	x	M	2	– ⁽¹⁾⁽²⁾	Polák <i>et al.</i> , 1995b
		f	n	M	5	– ⁽¹⁾	Karayiannis <i>et al.</i> , 1999
		f	x	M	4	– ⁽¹⁾⁽³⁾	Polák <i>et al.</i> , 1997
Julskit	Czech Rep.	f	c	M	5	– ⁽¹⁾	Sedlakova and Gallo, 1994
Karola	Czech Rep.	f	c	M	5	– ⁽¹⁾	Sedlakova and Gallo, 1994
Kinted	USA	f	n	M	4	– ⁽¹⁾	Balan and Stoian, 1995
Krupna	Yugoslavia	gh	c	M	3	– ⁽¹⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1		Rankovic <i>et al.</i> , 1999
Leronda	Czech Rep.	f	x	M	2	– ⁽¹⁾⁽²⁾	Polák <i>et al.</i> , 1995b
		f	x	M	4	– ^{(1) + (3)}	Polák <i>et al.</i> , 1997
Lito	Greece	f	x	M	4		Syrgiannidis and Mainou, 1991
		f	x	M	4	– ⁽¹⁾	Karayiannis and Mainou, 1994
		f	n	M	1		Audergon <i>et al.</i> , 1995b
		f	n	M	5	– ⁽¹⁾	Karayiannis <i>et al.</i> , 1999
Manitoba	USA	f	n	M	4		Balan and Stoian, 1995
NJA2	USA	gh	c	D	2	– ⁽¹⁾	Martínez-Gómez and Dicenta, 2000
		f	x	M	4	– ⁽¹⁾	Karayiannis and Mainou, 1994
		f	n	M	1		Audergon <i>et al.</i> , 1995b
		f	n	M	5	– ⁽¹⁾	Karayiannis <i>et al.</i> , 1999
NJA48	USA	f	n	M	4		Balan and Stoian, 1995
NJA53	USA	f	n	M	4		Balan and Stoian, 1995
NJA54	USA	f	n	M	4		Balan and Stoian, 1995
NJA56	USA	f	n	M	4		Balan and Stoian, 1995
NJA58	USA	f	n	M	0		Tradafiresfu and Topor, 1997
NJA59	USA	f	n	M	4		Balan and Stoian, 1995
Orange Red	USA	gh	c	D	2	– ⁽¹⁾	Fuchs <i>et al.</i> , 1998
Pandora	Greece	gh	c	D	1	– ⁽¹⁾	Martínez-Gómez and Dicenta, 2000
		f	x	M	4		Syrgiannidis and Mainou, 1991
		f	x	M	8	– ⁽¹⁾	Karayiannis and Mainou, 1994
		f	n	M	1		Audergon <i>et al.</i> , 1995b
		f	n	M	1		Audergon <i>et al.</i> , 1995b
		f	n	M	5	– ⁽¹⁾	Karayiannis <i>et al.</i> , 1999
Skoplsjanska	Czech Rep.	gh	c	M	3	– ⁽¹⁾	Dosba <i>et al.</i> , 1992
		f	n	M	1		Rankovic <i>et al.</i> , 1999

Table II. (continued)

Cultivar	Origin	Eval	Inoc	Isol	Year	D t	Reference
Stella	USA	gh	c	D	2		Audergon <i>et al</i> , 1994
		gh	c	D	2		Audergon <i>et al</i> , 1995a
		gh	c	D	4	– ⁽¹⁾	Martínez-Gómez and Dicenta, 2000
		f	n	M	8		Syrgiannidis, 1980
		gh	c	M	3	– ⁽¹⁾	Dosba <i>et al</i> , 1988
		f	n	M	4		Karayiannis, 1989
		gh	c	M	1	– ⁽¹⁾	Dosba <i>et al</i> , 1991
		gh	c	M	3	– ⁽¹⁾	Dosba <i>et al</i> , 1992
		f	x	M	4	– ⁽¹⁾	Karayiannis and Mainou, 1994
		f	n	M	1		Audergon <i>et al</i> , 1995b
		f	n	M	5		Audergon <i>et al</i> , 1995a
		f	n	M	5		Audergon <i>et al</i> , 1995a
		f	x	M	2	+ ⁽¹⁾ – ⁽²⁾	Polák <i>et al</i> , 1995b
		f	n	M	4		Balan and Stoian, 1995
		f	n	M			Rankovic <i>et al</i> , 1999
Veharda	Czech Rep	f	c	M	5	– ⁽¹⁾	Sedlakova and Gallo, 1994
Virosia	Germany	gh	c	D	2	– ⁽¹⁾	Fuchs <i>et al</i> , 1998

(?): unknown origin.

Eval: evaluation conditions (f = field, gh = greenhouse).

Inoc: inoculation method (n = natural, c = chip, x = grafting onto an infected tree).

Isol: isolate used (M = Marcus, D = Dideron).

Years: years or cycles of study.

D t: detection technique, ⁽¹⁾ ELISA (+ or –), ⁽²⁾ ISEM (+ or –), ⁽³⁾ IC-RT-PCR (+ or –).

3.1. Susceptible cultivars

The susceptible cultivars (Tab. I) have a wide geographic origin (Europe, Asia, Africa, Australia and America), and all showed a positive reaction when ELISA, ISEM, IC-RT-PCR or TP techniques were applied.

As regards the M and D strains, no differences were observed between the cultivars in terms of susceptibility (presence versus absence of symptoms) either on leaves or fruits ('Bebecou', 'Canino', 'Colomer', 'Corbató', 'Currot', 'Ginesta', 'Mitger', 'Palabras', 'Rojo Carlet', 'Screara', 'Tadeo' or 'Tiryntos'). However, in some cases, the M isolate may produce slightly more symptoms with a higher intensity than the D isolate, results which reflect the observations of Quiot *et al*. [41]. However, the data refer to a wide range of cultivars, which were evaluated in different locations under various environmental conditions and by different authors, a factor which should be taken into account when interpreting slight differences.

Susceptible cultivars presented a high degree of correlation between the intensity of the symptoms in both leaves and fruits. However, in some cultivars, such as the Spanish 'Damasco', 'Trujillos' and 'Velázquez', symptoms were much more intense in fruits than in the leaves [44]. As in the previous case, comparisons were not easy because of the different lengths of the evaluation periods and the different methods used.

3.2. Resistant cultivars

In resistant cultivars, symptoms in leaves or fruits have never been reported (Tab. II). Most of these cultivars are from North America, as in the case of 'Alfred', 'Farmingdale', 'Kinted', 'Manitoba', 'Orange Red', 'Stella', 'Harlayne', 'NJA2', 'NJA48', 'NJA53', 'NJA54', 'NJA56', 'NJA58' and 'NJA59'. Furthermore, the European resistant cultivars have as resistant parent an American cultivar, as in the case of 'Avilara' (French), 'Lito' and 'Pandora' (Greek) and

Table III. Apricot cultivars with uncertain resistance to plum pox potyvirus.

Cultivar	Origin	Level	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference
Badami	Iran	r	gh	C	M	3	0.0		– ⁽²⁾	Dosba <i>et al</i> , 1988
		t	gh	c	M	1	0.0		+ ⁽²⁾	Dosba <i>et al</i> , 1991
		s	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		s	f	n	M	1	3.0	1.0		Audergon <i>et al</i> , 1995b
Blenril	USA	s	f	n	M	4	1.9	2.0		Karayiannis, 1989
		r	f	n	M	1	0.0	0.0		Rankovic <i>et al</i> , 1999
Callatis	Romania	r	f	n	M	2	0.0			Tradafirescu and Topor, 1999
		s	f	n	M	4	2.0	2.8		Balan and Stoian, 1995
Chuang Zhi Hong	China	r	f	x	M	2	1.0		+ ⁽²⁾⁽³⁾	Polák <i>et al</i> , 1995b
		s	f	x	M	4	2.0	2.5	+ ⁽²⁾	Polák <i>et al</i> , 1997
Dacia	Romania	s	f	n	M	4	1.5	1.5		Balan and Stoian, 1995
		r	f	x	M	4	2.0	2.0	+ ⁽²⁾⁽⁴⁾	Polák <i>et al</i> , 1997
Excelsior	Romania	s	gh	c	M	1	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1991
		r	f	n	M	1	0.0	0.0	+ ⁽²⁾	Audergon <i>et al</i> , 1995b
Goldrich	USA	s	f	n	M	4	3.0	1.5		Balan and Stoian, 1995
		s	gh	c	D	2	+ ⁽¹⁾		+ ⁽²⁾	Fuchs <i>et al</i> , 1998
		r	gh	c	D	4	0.0		– ⁽²⁾	Martínez-Gómez and Dicenta, 2000
		r	gh	c	M	3	0.0		– ⁽²⁾	Dosba <i>et al</i> , 1992
		r	f	x	M	2	0.0	0.0	– ⁽²⁾	Karayiannis and Mainou, 1994
		t	f	n	M	1	0.0			Audergon <i>et al</i> , 1995b
		t	f	n	M	1	+ ⁽¹⁾			Audergon <i>et al</i> , 1995a
		s	f	x	M	1	2.0		+ ⁽²⁾⁽³⁾	Polák <i>et al</i> , 1995b
		t	f	n	M	5	+ ⁽¹⁾			Karayiannis <i>et al.</i> , 1999
		s	f	x	M	4	2.0	2.5	+ ⁽²⁾⁽⁴⁾	Polák <i>et al</i> , 1997
Harcot	Canada	r	gh	c	D	2	0.0	0.0		Audergon <i>et al</i> , 1994
		r	gh	c	D	2	0.0			Audergon <i>et al</i> , 1995a
		r	gh	c	D	4	0.0		– ⁽²⁾	Martínez-Gómez and Dicenta, 2000
		r	gh	c	M	3	0.0		– ⁽²⁾	Dosba <i>et al</i> , 1988
		s	f	n	M	4	1.2	1.0		Karayiannis, 1989
		r	gh	c	M	1	0.0		– ⁽²⁾	Dosba <i>et al</i> , 1991
		s	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1992
		s	f	n	M	6	1.2	1.5		Audergon <i>et al</i> , 1995a
		s	f	x	M	1	2.5	2.5		Audergon <i>et al</i> , 1995a
		s	f	x	M	1	2.0		+ ⁽²⁾⁽³⁾	Polák <i>et al</i> , 1995b
		r	f	n	M	1	0.0			Tradafirescu and Topor, 1999
		s	f	n	M	1	+ ⁽¹⁾		+ ⁽¹⁾	Rankovic <i>et al</i> , 1999
		s	f	x	M	4	1.5	1.0	+ ⁽²⁾⁽⁴⁾	Polák <i>et al</i> , 1997
Harval	Canada	s	f	x	M	2	3.0		+ ⁽²⁾⁽³⁾	Polák <i>et al</i> , 1995b
		r	f	x	M	4	1.0	1.0	+ ⁽²⁾⁽⁴⁾	Polák <i>et al</i> , 1997
Henderson	USA	r	gh	c	D	2	0.0	0.0		Audergon <i>et al</i> , 1994
		r	gh	c	D	2	0.0			Audergon <i>et al</i> , 1995a
		s	gh	c	M	3	+ ⁽¹⁾		+ ⁽²⁾	Dosba <i>et al</i> , 1988
		r	gh	c	M	1	0.0		– ⁽²⁾	Dosba <i>et al.</i> ,1991
		r	gh	c	M	3	0.0		– ⁽²⁾	Dosba <i>et al.</i> ,1992
		r	f	x	M	2	0.0	0.0	– ⁽²⁾	Karayiannis and Mainou ,1994
		r	f	n	M	1	0.0	0.0		Audergon <i>et al</i> , 1995b
		s	f	n	M	4	1.0	2.5		Balan and Stoian, 1995
t	f	n	M	5	0.0			Karayiannis <i>et al.</i> , 1999		

Table III. (continued).

Cultivar	Origin	Level	Eval	Inoc	Isol	Year	Le s	Fr s	D t	Reference	
Marii de Cenad	Romania	r	gh	c	M	3	0.0		– ⁽²⁾	Dosba <i>et al.</i> , 1992	
		s	f	x	M	1	2.0		+ ⁽²⁾⁽³⁾	Polák <i>et al.</i> , 1995b	
		r	f	x	M	4	1.0	1.0	– ⁽²⁾⁽⁴⁾	Polák <i>et al.</i> , 1997	
Mamaia	Romania	r	f	n	M	1	0.0	0.0		Audergon <i>et al.</i> , 1995b	
		s	f	n	M	4	3.0	1.5		Balan and Stoian, 1995	
		s	f	n	M	2	3.0			Tradafirescu and Topor, 1999	
Pentagonála	?	t	f	x	M	4	2.0	2.0	+ ⁽²⁾⁽⁴⁾	Polák <i>et al.</i> , 1997	
Riland	USA	r	f	n	M	0.0	0.0			Rankovic <i>et al.</i> , 1999	
		s	f	n	M	4	3.0	3.0		Balan and Stoian, 1995	
Roxana	?	t	f	n	M	1	0.0			Audergon <i>et al.</i> , 1995b	
Stark Early Orange	USA	r	gh	c	D	2	0.0	0.0		Audergon <i>et al.</i> , 1994	
		r	gh	c	D	1	0.0				Audergon <i>et al.</i> , 1995a
		t	gh	c	D	2				+ ⁽²⁾	Fuchs <i>et al.</i> , 1998
		r	gh	c	D	2	0.0			– ⁽²⁾	Martínez-Gómez and Dicenta, 2000
		r	f	n	M	8	0.0	0.0			Syrgiannidis, 1980
		r	gh	c	M	3	0.0			– ⁽²⁾	Dosba <i>et al.</i> , 1988
		r	f	n	M	4	0.0	0.0			Karayiannis, 1989
		r	gh	c	M	1	0.0			– ⁽²⁾	Dosba <i>et al.</i> , 1991
		r	gh	c	M	3	0.0			– ⁽²⁾	Dosba <i>et al.</i> , 1992
		r	f	x	M	5	0.0	0.0		– ⁽²⁾	Karayiannis and Mainou, 1994
		r	f	n	M	1	0.0	0.0			Audergon <i>et al.</i> , 1995b
		r	f	n	M	5	0.0	0.0			Audergon <i>et al.</i> , 1995a
		r	f	x	M	5	0.0	0.0			Audergon <i>et al.</i> , 1995a
		r	f	x	M	2	0.5			+ ⁽²⁾⁽³⁾	Polák <i>et al.</i> , 1995b
		r	f	n	M	4	3.0	3.0			Balan and Stoian, 1995
		r	f	n	M	2	0.0				Tradafirescu and Topor, 1999
r	f	x	M	4	1.0	0.0		+ ⁽²⁾⁽⁴⁾	Polák <i>et al.</i> , 1997		
r	f	n	M	5	0.0	0.0		– ⁽²⁾	Karayiannis <i>et al.</i> , 1999		
Sundrop	Canada	s	f	n	M	4	3.0	2.5		Balan and Stoian, 1995	
		r	f	x	M	4	1.5	1.5	+ ⁽²⁾⁽⁴⁾	Polák <i>et al.</i> , 1997	
Sunglo	USA	r	gh	c	M	3	0.0		– ⁽²⁾	Dosba <i>et al.</i> , 1992	
		r	f	x	M	4	0.0	0.0	– ⁽²⁾	Karayiannis and Mainou, 1994	
		r	f	n	M	1	0.0	0.0		Audergon <i>et al.</i> , 1995b	
Veecot	Canada	s	f	n	M	4	1.0	1.0		Balan and Stoian, 1995	
		r	f	n	M	5	0.0	0.0	– ⁽²⁾	Karayiannis <i>et al.</i> , 1999	
		r	gh	c	M	3	0.0		– ⁽²⁾	Dosba <i>et al.</i> , 1992	
		r	f	x	M	9	0.0	0.0	– ⁽²⁾	Karayiannis and Mainou, 1994	
		r	f	c	M	5	0.0	0.0	– ⁽²⁾	Sedlakova and Gallo, 1994	
Vegama	Czech Rep	r	f	n	M	1	0.0	0.0		Audergon <i>et al.</i> , 1995b	
		s	f	x	M	1	2.0		+ ⁽¹⁾	+ ⁽²⁾⁽³⁾	Polák <i>et al.</i> , 1995b
		r	f	c	M	5	0.0	0.0	– ⁽²⁾	Sedlakova and Gallo, 1994	
		s	f	x	M	4	3.0	3.0	+ ⁽²⁾⁽⁴⁾	Polák <i>et al.</i> , 1997	

(?): unknown origin.

Level: level of resistance (r = resistant, s = susceptible, t = tolerant).

Eval: evaluation conditions (f = field, gh = greenhouse).

Inoc: inoculation method (n = natural, c = chip, x = grafting onto an infected tree).

Isol: isolate used (M = Marcus, D = Dideron).

Years: years or cycles of study.

Le s: symptoms in leaves (0–3), ⁽¹⁾ scale not specified.Fr s: symptoms in fruits (0–3), ⁽¹⁾ scale not specified.D t: detection technique, ⁽²⁾ ELISA (+ or –), ⁽³⁾ ISEM (+ or –), ⁽⁴⁾ IC-RT-PCR (+ or –).

'Leronda' and 'Veharda' (Czech). North American cultivars are obviously a clear source of resistance.

In addition, other sources of resistance have been found in 'Brevira' and 'Virosia' (German), 'Julskit', 'Karola' and 'Skopljanska' (Czech), 'Ceccona' (Italian), 'Krupna' (Yugoslav) and 'Cais Olanda' (unknown origin), although no clear information can be given on their origin. Furthermore, more experiments are necessary to evaluate the maintenance of their resistance using different strains and in different conditions of evaluation.

ELISA, ISEM or IC-RT-PCR, which were performed on the resistant cultivars 'Avilara', 'Harlayne', 'Julskit', 'Karola', 'Kinted', 'Krupna', 'Lito', 'NJA2', 'Pandora' and 'Veharda', showed a negative reaction [19, 20, 28, 29, 32, 39, 40]. On the other hand, 'Stella' tested ELISA-positive but ISEM was negative [39], and 'Leronda' tested ELISA-negative and IC-PCR-positive [40].

Unfortunately, not all the resistant sources were evaluated against all the different strains. 'Alfred', 'Farmingdale', 'Kinted', 'Manitoba', 'NJA48', 'NJA53', 'NJA54', 'NJA56', 'NJA58', 'NJA59', 'Lito', 'Leronda', 'Veharda', 'Julskit', 'Karola', 'Skopljanska', 'Ceccona', 'Krupna' and 'Cais Olanda', were assayed only against M type isolates, while 'Brevira', 'Orange Red' and 'Virosia' were only evaluated with D type isolates. Only, 'Avilara', 'Harlayne', 'NJA2', 'Pandora' and 'Stella', were assayed with both D and M strains. Some authors [20, 24, 40] have classified 'Harlayne' as 'immune'.

3.3. Cultivars of uncertain classification

Table III shows the cultivars described using different classifications depending on the author in question. Mostly, they come from North America and are alternatively described as resistant, tolerant or susceptible. Such is the case with 'Bleril', 'Goldrich', 'Henderson', 'Riland', 'Stark Early Orange', or 'Sunglo' (American) and 'Harcot', 'Harval', 'Sundrop' or 'Veecot' (Canadian).

Another group is composed of the cultivars 'Callatis', 'Dacia', 'Excelsior', 'Mamaia' and

'Marii de Cenad' (Romanian), 'Vegama' (Czech), 'Pentagonála' and 'Roxana' (unknown origin), 'Badami' (Iranian) and 'Chuang Zhi Hong' (Chinese). Little information is available on this group, and some cultivars have occasionally been described as resistant or tolerant. Further investigations, using different conditions and isolates are necessary before they can be definitively classified.

Analysis of the data in Table III seems to indicate that some cultivars can be classified as resistant or susceptible. 'Badami' seems to be susceptible to M type (in spite of the one reference describing it as resistant). 'Harcot' is probably resistant to D type and susceptible to M type. The classification of 'Henderson' and 'Goldrich' remains unclear because, although they have been described as susceptible by several authors, these cultivars were found to be resistant after two years of being grafted onto very diseased trees [28].

The contradictory information concerning the level of resistance of these cultivars could be explained by the different isolate types used (Marcus or Dideron), different methodologies (evaluation conditions, inoculation type, number of years studied, etc.) or the authenticity and sanitary state of the material examined.

Other uncontrolled factors, such as the evolution of the inoculum during the long period of evaluation, the variability of the pathogen, and possible interactions in plants infected with other pathogens could also have affected the results obtained by the authors.

For these reasons, any classification of cultivars into susceptible or resistant should be accompanied by details of the methods and isolates used. It would be beneficial if the same evaluation method could be established in all countries so that the results obtained could be better contrasted.

On the other hand, breeders could use as sources of resistance cultivars such as 'Goldrich', 'Harcot', 'Henderson', 'Stark Early Orange', 'Sunglo' or 'Veecot', which although susceptible to some isolates, are resistant to the isolates commonly found in the countries where breeding programmes are being carried out. New European resistant cultivars such as 'Avilara', 'Lito' and 'Pandora',

(descendants of 'Henderson' or 'Stark Early Orange') have been obtained in this way.

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