

Current Status of Vegetative Compatibility Groups in *Fusarium oxysporum*

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Thirty-eight *formae speciales* (ff.sp.) of *Fusarium oxysporum* which have been subjected to vegetative compatibility grouping (VCG) analysis are listed, along with their updated 3-digit numerical codes. The number of VCGs identified within a *forma specialis* ranges from one (in 11 cases) to 24. Between two and six VCGs were identified in each of 20 ff.spp., whereas seven VCGs or more were identified in the remaining ff.spp. VCGs to which 4-digit numerical codes have been given are listed for 30 ff.spp.

KEY WORDS: *Fusarium oxysporum*; systematic numbering; VCG coordination; vegetative compatibility.

INTRODUCTION

Fusarium oxysporum Schlechtend.: Fr. is a ubiquitous soil-inhabiting fungal species consisting of both pathogenic and non-pathogenic strains. Based on their host specificity, the pathogenic strains of *F. oxysporum* are divided into *formae speciales* (6,17,54). Since the mid-1980s, an increasing number of *formae speciales* have also been characterized by the vegetative-compatibility grouping (VCG) method, following the approach and procedure described by Puhalla (134). In his original article, Puhalla (134) proposed a numbering system whereby VCGs were related to *formae speciales* by 3-digit numerical codes; he noted that a great deal of cooperation would be necessary to standardize this system. However, in the absence of effective cooperation, problems have arisen involving improper numbering of VCGs, as discussed recently (78). In addition, researchers often refrain from numbering the newly discovered VCGs of their studies.

In recognition of the significance of VCGs for understanding population genetics, diversity and evolution of *F. oxysporum* (18,24,25,47,77,80,92-94,155), the initiative has been taken to coordinate the systematic numbering of VCGs. As an immediate consequence of this initiative, a procedure is being implemented according to which code numbers for new VCGs are assigned by a 'VCG numbering coordinator' prior to publication (78). This note is intended to report on the first step I have taken (serving as the coordinator for 1998) to promote standardization of the numbering system. The first step consists of two parts: (i) improperly numbered VCGs were re-numbered, in order to remove duplications and other inconsistencies; and (ii) numerical codes were assigned to yet unnumbered *formae speciales* and VCGs thereof. The 38 *formae speciales* which have been subjected to VCG analysis are listed in Table 1, along with their hosts and the updated 3-digit numerical codes. The numerical codes previously assigned to 23 of these *formae speciales* have been retained.

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(i) Re-numbering *formae speciales*

Due to duplication (overlap) with other *formae speciales*, the previous numerical codes of f.sp. *basilici* and f.sp. *melongenae* (016- and 017-, respectively) (78) are replaced by new ones (020- and 032-, respectively).

Of the two numerical codes (001-; 014-) independently given to f.sp. *elaeidis* (78), the former constitutes a duplication with another *forma specialis* and is deleted, retaining 014- as the valid code.

The numerical code 010- had previously been given to a group of three *formae speciales* (*conglutinans*, *matthioli* and *raphani*) attacking crucifers (78). This code is now retained exclusively for f.sp. *conglutinans*, while new codes are given to f.sp. *matthioli* (021-) and f.sp. *raphani* (022-).

(ii) Numbering newly characterized *formae speciales*

Numerical codes are given to 11 yet unnumbered *formae speciales* (Table 1): *batatas*, *betae*, *canariensis*, *ciceris*, *erythroxyli*, *lactucum*, *lupini*, *nicotianae*, *papaveris*, *spinaciae* and *tuberosi*.

Numbering of VCGs

According to Puhalla's numbering system (134), VCGs within a *forma specialis* are distinguished by a series of one or two (possibly more?) digits which follow the 3-digit numerical code of the *forma specialis*. In Table 2, the *formae speciales* from Table 1 are listed by their numerical codes, along with the total number of VCGs found within each *forma specialis* to date and the serial numbers given to them. Whereas most of the listed VCG serial numbers are those given by the researchers, several others have resulted from the re-numbering and the new numbering mentioned above. When only one VCG has been recognized in a *forma specialis* (*canariensis*, *ciceris*, *lactucum*), its serial number was automatically determined by adding the digit 0 after the f.sp. code (78). Similarly, automatic VCG numbering was applied following the re-numbering of f.sp. *basilici*, *matthioli*, *raphani* and *melongenae*. This procedure could not be applied to *formae speciales* with more than one VCG, because VCGs must be related to specific groups of isolates.

In principle, the numbers given to VCGs within a *forma specialis* should be consecutive (Table 2). However, due to 'missing links', these series are discontinuous in the following *formae speciales*:

- *conglutinans*. VCGs 0102 (f.sp. *matthioli*) and 0103 (f.sp. *raphani*) (19,81) were removed from f.sp. code 010- which now includes only f.sp. *conglutinans*.
- *cubense*. VCG 0127 was cancelled (122).
- *dianthi*. VCGs 0023, 0024 and 0026 have been reclassified as *F. redolens*, or incorporated into other VCGs (9).
- *melonis*. VCG 0137 included a single avirulent isolate (62).
- *radicis-lycopersici*. VCG 0095 (75) contained a single isolate, now suspected as misclassified *Fusarium* sp.
- *vasinfectum*. VCG 01110 (39) was cancelled (D. Fernandez, personal communication).

TABLE 1. Vegetative compatibility groups of *Fusarium oxysporum* listed by *forma specialis* (f.sp.)

<i>forma specialis</i>	Host	f.sp. code	References
<i>albedinis</i>	<i>Phoenix dactylifera</i>	017-	22,40–42,144–146
<i>apii</i>	<i>Apium</i>	001-	26,28,132–134,147
<i>asparagi</i>	<i>Asparagus</i>	100-	14,37,89
<i>basilici</i>	<i>Ocimum</i>	020- ^z	38,70
<i>batatas</i>	<i>Ipomoea</i>	036-	23
<i>betae</i>	<i>Beta</i>	027-	56,57
<i>canariensis</i>	<i>Phoenix canariensis</i>	024-	
<i>chrysanthemi</i>	<i>Chrysanthemum</i>	005-	26,134
<i>ciceris</i>	<i>Cicer</i>	028-	110
<i>conglutinans</i>	<i>Brassica</i>	010-	19,26,81,134
<i>cubense</i>	<i>Musa</i>	012-	11–13,16,20,26,58,79,82,83,86,101,104,106,107,111–129,134,142
<i>cucumerinum</i>	<i>Cucumis sativus</i>	018-	1,68,148
<i>cyclaminis</i>	<i>Cyclamen</i>	015-	157
<i>dianthi</i>	<i>Dianthus</i>	002-	2,8,9,26,32,45,65,66,71,97,98,102,130,134,138,151
<i>elaeidis</i>	<i>Elaeis</i>	014- ^y	31,44,108
<i>erythroxyli</i>	<i>Erythroxyllum</i>	029-	109,141
<i>gladioli</i>	<i>Gladiolus</i>	034-	7,100,139
<i>lactucum</i>	<i>Lactuca</i>	030-	60
<i>lilii</i>	<i>Lilium</i>	019-	7,95
<i>lupini</i>	<i>Lupinus</i>	031-	136–138
<i>lycopersici</i>	<i>Lycopersicon</i>	003-	26,33,34,36,67,74,84,85,87,99,103,134,135
<i>matthioli</i>	<i>Matthiola</i>	021- ^x	19,81
<i>medicaginis</i>	<i>Medicago</i>	004-	26,134
<i>melongenae</i>	<i>Solanum melongena</i>	032- ^w	68
<i>melonis</i>	<i>Cucumis melo</i>	013-	3–5,26,46,48,52,53,55,61–64,73,158
<i>nicotianae</i>	<i>Nicotiana</i>	037-	23,88
<i>niveum</i>	<i>Citrullus</i>	008-	26,59,76,90,134
<i>papaveris</i>	<i>Papaver</i>	025-	
<i>phaseoli</i>	<i>Phaseolus</i>	016-	156
<i>pisi</i>	<i>Pisum</i>	007-	15,26,29,131,134,138,154
<i>radicis-cucumerinum</i>	<i>Cucumis sativus</i>	026-	148
<i>radicis-lycopersici</i>	<i>Lycopersicon</i>	009-	26,30,75,96,134,140,153
<i>raphani</i>	<i>Raphanus</i>	022- ^c	19,81
<i>spinaciae</i>	<i>Spinacia</i>	033-	43
<i>tracheiphilum</i>	<i>Vigna</i>	006-	26,134
<i>tuberosi</i>	<i>Solanum tuberosum</i>	035-	149
<i>tulipae</i>	<i>Tulipa</i>	023-	7
<i>vasinfectum</i>	<i>Gossypium</i>	011-	10,21,22,26,39,72,105,134,152

^z Formerly VCG 016- (70).

^y Formerly also VCG 001- (31).

^x Formerly included in VCG 010- (19,81).

^w Formerly VCG 017- (68).

TABLE 2. Vegetative compatibility groups (VCGs) of *Fusarium oxysporum* listed by serial numbers of *forma specialis* (f.sp.) codes

f.sp. code	<i>forma specialis</i>	Assigned VCG numbers	No. of VCGs
001-	<i>apii</i>	0010-0012	3
002-	<i>dianthi</i>	0020-0022, 0025, 0027, 0028	6
003-	<i>lycopersici</i>	0030-0033	4+ ^z
004-	<i>medicaginis</i>	0040, 0041	2
005-	<i>chrysanthemi</i>	0050, 0051	2
006-	<i>tracheiphilum</i>	0060	1
007-	<i>pisi</i>	0070	5? ^y +
008-	<i>niveum</i>	0080-0082	3
009-	<i>radicis-lycopersici</i> ^z	0090-0094, 0096-0099	9+
010-	<i>conglutinans</i>	0100, 0101, 0104	3?
011-	<i>vasinfectum</i>	0110-0119, 01111, 01112	12+
012-	<i>cubense</i> ^w	0120-0126, 0128-01224	24+
013-	<i>melonis</i> ^v	0130-0136, 0138	8+
014-	<i>elaeidis</i>	0140, 0141	5+
015-	<i>cyclaminis</i>	0151-0153	3
016-	<i>phaseoli</i>	0161-0165	5+
017-	<i>albedinis</i>	0170	1
018-	<i>cucumerinum</i>	0180-0183	6+
019-	<i>lilii</i>	0190	1
020-	<i>basilici</i>	0200	1
021-	<i>matthioli</i>	0210	1
022-	<i>raphani</i>	0220	1
023-	<i>tulipae</i>	0230	1
024-	<i>canariensis</i>	0240	1+
025-	<i>papaveris</i>		
026-	<i>radicis-cucumerinum</i> ^u	0260, 0261	2
027-	<i>betae</i>		7+
028-	<i>ciceris</i>	0280	1
029-	<i>erythroxyli</i>		2
030-	<i>lactucum</i>	0300	1
031-	<i>lupini</i>		2?
032-	<i>melongenae</i>	0320	1
033-	<i>spinaciae</i>		3
034-	<i>gladioli</i>	0340-0343	4
035-	<i>tuberosi</i>		6
036-	<i>batatas</i>		2+
037-	<i>nicotianae</i>		2+
100-	<i>asparagi</i>	1001-1008	8+

^z+: Additional isolates are not compatible with the established VCGs.

^y?: Two or more of these VCGs may overlap.

^x Vegetative compatibility has been demonstrated between VCGs 0090/0092 (75); subgroups were found in VCGs 0090, 0091, and 0094 (75).

^w Vegetative compatibility has been demonstrated between VCGs 0120/01215, 0124/0125/0128/01220, and 01213/01216 (127); subgroups were found in VCG 0123 (R. Ploetz, personal communication).

^v Subgroups were found in VCG 0138 (73).

^u Vegetative compatibility has been demonstrated between VCGs 0260/0261 (148).

Single-member VCGs

As explained previously, self-compatible single-member VCGs usually should not be numbered (78). Within a *forma specialis* they are grouped in an artificial VCG, designated by the f.sp. code followed by a hyphen. For example, such isolates within f.sp. *lycopersici* will be assigned to the artificial VCG 003- (33). The presence of such putative VCGs is indicated in Table 2 (footnote z).

Heterokaryon self-incompatibility (HSI)

HSI is evident by the inability of complementary *nit* mutants of an isolate to form complementary heterokaryons with each other (61,92,93). Although complementation can occasionally be observed in pairings with strongly anastomosing testers, HSI strains usually cannot be assigned to a VCG. In order to distinguish them from self-compatible single-member VCGs, HSI strains should be designated as such; using the above example, an f.sp. *lycopersici* isolate will be assigned to VCG 003-HSI.

Non-pathogenic *F. oxysporum*

In addition to pathogenic strains (Table 1; 150), vegetative compatibility has also been determined among non-pathogenic populations of *F. oxysporum* (27,35,49-51,69,91,143). In general, such populations are highly variable, and should not be included in the numbering system of the pathogenic populations (78).

The current status of VCGs in *F. oxysporum* is summarized in Tables 1 and 2. *Notes concerning omissions or errors in the Tables and references will be very much appreciated.*

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