CARNATION WILT DISEASES CAUSED BY FUNGI IN FINLAND

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The wilting disease of carnation (*Dianthus caryophyllus* L.) is caused by bacteria and fungi, among which the most often encountered are the *Fusarium*-fungi, *Phialophora cinerescens* (Wr.) van Beyma (syn. *Verticillium cinerescens* Wr.), and the bacteria *Pectobacterium parthenii* Starr. var. *dianthicola* Hellm. and *Pseudomonas caryophylli* (Burkh.) Starr. & Burkh. (cf. SCHOLTEN 1955, HELLMERS 1958, PAPE 1964). For the carnation pathogenic form of *F. oxysporum* (Schl.) Sn. & H. has been given the name *F. oxysporum* (Schl.) Sn. & H. f. *dianthi* (Prill. & Delacr.) Sn. & H.

Material

In 1967—68 the Department of Plant Pathology studied the wilting disease of carnation in Finland. Preliminary results have already been published (RUOTSALAINEN 1969). In order to find out about the occurrence of the disease and the fungi causing it, enquiry forms were sent to 120 carnation growers, and in addition, samples were collected from a number of nurseries. Samples were received from a total of 51 nurseries (Table 1).

The fungi were isolated from the diseased plants by sterile cutting of samples onto oatmeal agar from the root, the base, and from a healthy looking part some 20—30 cm above the base and from the cut surfaces. From a total of 81 plants 177 isolations were made, and from these, 17 species of funcus were identified (Table 2).

The *Fusarium* fungi, of which there were 10 species, proved to be the most commonly occurring in carnations infected with wilting diseases. The most common was *F. oxysporum*, which represented 31.1 % of the isolated fungi. Other spesies common were *F. arthrosporioides*, 7.3 %, *F. avenaceum*, 10.7 %, *F. culmorum*, 8.5 %, and *Alternaria tenuis*, 7.9 %, as well as *Cladosporium* sp., 9.0 %. Two samples of *P. cinerescens*, 1.1 %, were found. Some fungi of the *Penicillium*, *Aspergillus* and other genera occurred as epiphytes, and do not appear in Table 1.

Table 1. Nurseries from which the carnation samples were taken, from 1967—68.

Nursery	Locality	Alternaria dianthi	A. tenuis	Botrytis cinerea	Cladosporium sp	Cylindrocarpon didymum	Fusarium arthrosporioides	F. avenaceum	F. culmorum	F. graminearum	F. lateritium	F. oxysporum	F. „ var. redolens	F. semitectum	F. solani	F. sporotrichioides	Phialophora cinerescens	Phoma sp.	Rhizoctonia solani	Rhizopus sp.	Stemphylium sp.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ahopellon puutarha	Imatra		2									2									
Bjomaan „	Helsinki				1							1									
Aackas-tilan „	Helsingin mlk		1	1	2		2		1	1		1							1		
Ekengrenin „	Hamina								1			2									
Elomaa	Turku			1				1													
Holmberg	Sipoo											1									
Huhtamäen puutarha	Laihia				1																
Huhtasen „	Rauma				1	1			1	1								1			1
Huiskula Oy	Maaria											2									
Ilpoisten kauppapuutarha	Turku											1									
Jaalan puutarha	Raisio				1				1			1			1						
Kaarnikon kauppapuutarha	Turku		1			1	1	1	1			1									
Kangaspunta	Helsingin mlk			1	2	1						1							1		
Kempeleen puutarhurikoulu	Kempele						1	1				1									
Koski, Janne	Kokemäki				1		1					1									
Koskinen, Toivo	Helsinki							1				4									
Kukkolan puutarha	Tampere	1		1					1			2							1		
Lahtelan „	Kangasala		1									3									
Lepolan kauppapuutarha	Maaria							1									1		1		
Liikkasen puutarha	Hamina		1									1									
Lindberg, E	Kerava							1													
Loimaan ev. kansanopisto	Loimaa		1									1									
Lyyvaara, Jali	Turku											1									
Mattila, Ensio	Kangasala							3				3									
Mattilan puutarha	Orimattila			1			1					2									
Naakan „	Anjala		1																		
Narinen, Matti	Mussalo				1								1								
Nyystilä, Arvo	Toijala							1													
Olsson, E	Kymi					1						1									
Pekonen	Lahti				2		1					2									
Peuralinna	Helsingin mlk																1				
Pitkäniemen sairaalan puut.	Nokia							1	2			2									
Poukan puutarha	Laitila							1				2							1		
Puutarhantutkimuslaitos	Piikkiö		1																		
Pyhtään kauppapuutarha	Pyhtää			1															1		
Rapilan puutarha	Laihia				1				2			1									
Reitkallin puutarhakoulu	Vehkalahti											1				1			1	1	
Salmen puutarha	Kivijärvi											1									
Salmi, Esko	Vanaja								1			1									
Satakunnan parantolan puut.	Harjavalta		1	1	1										1						1
Satoturve Oy	Tuusula						1	1													
Siikin puutarha	Imatra								1												
Sjöberg, Stig	Helsingin mlk		2				1	1	1			1									1
Sjölund, H. V.	Helsingin mlk							1				1									
Suutari, V. A.	Karhula		1				1	4	1			4							1		
Tiihonen ja K:ni	Kausala		1	1								1			1						
Tyynelän puutarha	Punkasalmi						1			1	1	3							1	3	
Uutela	Helsingin mlk			1			1														
Valkeaniemen puutarha	Forssa				2		1		1			1		1							
Vesan „ Oy	Pori			1								1									
Tuntematon																1					
		1	14	10	16	4	13	19	15	3	1	55	1	1	3	2	2	1	9	4	3

The studied material revealed relatively few samples of *P. cinerescens*, the occurrence of which has already been established in Finland (TALVIA 1964—1967). This fungus has been found also in many other countries. In Sweden *P. cinerescens* was very rare in 1968, while the *Fusarium* species have been common, in particular *F. oxysporum* (SÖDERGREN 1968, von WACHENFELT 1968). In Bulgaria, the main fungi causing diseases in carnation in recent years have been *F. roseum* Link (syn. *F. graminearum* Schwabe) and *F. oxysporum* Schl. f. sp. *dianthi* (Prill. & Delacr.) Snyder & Hansen (ALEKSANDROVA 1968). In Holland there was widespread occurrence of *F. oxysporum* in 1966 (SCHOLTEN 1966).

In cuttings and young growing plants the *Fusarium* fungi cause brown, wet and soft rot in the lowest parts of the stem. The roots are decomposed or not formed at all. The rot is generally confined to the base of the stem, but it may also spread well up to the top

Table 2. Fungi isolated from carnation samples.

	Samples	%		Samples	%
Alternaria dianthi Stev. & Hall.	1	0.6	*F. oxysporum* (Schl.) Sn. & H. var.		
A. tenuis Neerg.	14	7.9	*redolens* (Wr.) Gordon	1	0.6
Botrytis cinerea Pers. ex Fr.	10	5.9	*F. semitectum* Berk. & Rav.	1	0.6
Cladosporium sp.	16	9.0	*F. solanti* (Mart.) Sn. & H.	3	1.7
Cylindrocarpon didymum (Hart.) Wr.	4	2.3	*F. sporothrichioides* Sherb.	2	1.1
Fusarium arthrosporioides Sherb.	13	7.3	*Phialophora cinerescens* (Wr.) v. Beyma	2	1.1
F. avenaceum (Fr.) Sacc.	19	10.7	*Phoma* sp.	11	0.6
F. culmorum (W. G. Sm.) Sacc.	15	8.5	*Rhizoctonia solani* Kühn	9	5.1
F. graminearum Schwabe	3	1.7	*Rhizopus* sp.	4	2.3
F. lateritium (Nees) Sn. & H.	1	0.6	*Stemphylium* sp.	3	1.7
F. oxysporum (Schl.) Sn. & H.	55	31.1			

parts of young plants. If infection has been weak, the pith in the cross section of the stem is brown, once infection has developed further, however, the whole stem becomes rotten and hollow. In older plants the rot is dry (SCHOLTEN 1955, HELLMERS 1958). Wilting caused by *F. oxysporum* occurs together with collar-fusariosis caused by several other *Fusarium* species. In these instances it is difficult to distinguish between these diseases without pure cultures. In collar-fusariosis the base of the stem has rotted, while wilting caused by *F. oxysporum* is systemic. Both diseases bring about wilting and loss in yield. *F. oxysporum* is more destructive than other *Fusarium* fungi owing to the fact that it may penetrate the roots of the carnation in soil. Other *Fusarium* species penetrate the carnation only through the cut surfaces of the cuttings, through torn parts of older plants, through damaged places in roots and stems, and in particular through the surfaces where branches have been cut off or where the flowers have been cut or broken off (Pape 1964).

Plants damaged by *P. cinerescens* wilt gradually. The wilting leaves turn yellow (straw coloured) and often curl up somewhat. A cross-section of the stem, taken 20—40 cm from the soil surface, shows a clear brown ring to have developed within the bark. The roots remain healthy and do not come off if the plant is pulled up from the soil (SCHOLTEN 1955, HELLMERS 1958).

The largest amount of fungi, totalling 15 species, was isolated from the base of the stem. There were missing *Cylindrocarpon didymum*, which is a typical root pathogen, *Alter-*

naria dianthi, which has been found higher up in the stem, and *F. sporothrichioides* and *Phoma* sp. which were revealed by cross-section of the stem. The species found in all parts of the plant were *Botrytis cinerea*, *F. arthrosporioides*, *F. avenaceum*, *F. culmorum*, *F. oxysporum* and *Rhizoctonia solani*. *R. solani* causes stem rot in conditions unfavourable for carnation growing (GUBA 1945, PAPE 1964). The carnations had been infected by *A. tenuis*, *B. cinerea*, *Cladosporium* sp., *F. oxysporum*. *F. sporothrichioides* and *Phoma* sp. through cut surfaces. With a couple of exceptions, *Fusarium* fungi were found in all the greenhouses (Table 1).

Inoculation trials

I n o c u l a t i o n t h r o u g h s o i l. The rooted carnation cuttings used in the test were inoculated two weeks after planting with fungus suspension, with which the soil was sprayed. The trial comprised 36 carnation-plants. The results were as follows:

	Number of wilted plants	
	after 8 weeks	after 12 weeks
Alternaria tenuis	0	0
Fusarium avenaceum	0	0
F. culmorum	0	0
F. oxysporum a	0	0
» b	4	6
Control	0	0

Two different isolates, a and b, of *F. oxysporum* were used in the test. Of all the fungi used, only the b-isolate of *F. oxysporum* was able to destroy the carnations through the soil and to cause their complete wilting within three months.

I n o c u l a t i o n f r o m t h e a i r. The carnations used in the test were 6 months old. After being cut to lengths of 0.5 m they were inoculated directly by spraying the cut surfaces with fungi suspension. The wilting appeared as shrinking of the stem, wilting and yellowing in the cut internodes, progressing in some branches downwards through several internodes. In healthy cut surfaces the stem was green and fresh. The results were as follows:

	No. of cut stems	Wilting percentage after		
		3 weeks	6 weeks	8 weeks
Alternaria tenuis	21	5	81	81
Fusarium avenaceum	24	4	83	88
F. culmorum	21	62	81	81
F. oxysporum	21	19	100	100
Control	41	0	15	29

All the tested fungi were able to penetrate the plants through their broken surfaces, or to cause in that way at least partial wilting. Most injurious was *F. oxysporum*. Even in the control, which had not been inoculated, wilting began to take place in 29 % of the cut stems. From these *Rhizopus* sp. was isolated.

Control trials

The fungicide-sprays used in the control of the wilt disease caused by *F. oxysporum* were Dithane M-45 (mancozeb 80 %), Orthocide 50 (captan 50 %), and Pomarsol Forte (thiram 80 %). The soil had been inoculated as in the previous trial with the isolate *F. oxysporum b*. The first spraying was carried out two weeks after inoculation and was then repeated at fortnightly intervals. The following results were obtained (D = Dithane M-45, O = Orthocide 50, P = Pomarsol Forte):

Sprayings			Wilted %	
22/7	5/8	19/8	9/8	23/8
D	D	D	50	100
O	O	O	50	91
P	P	P	41	91
D	O	D	45	86
D	P	D	59	95
O	P	O	59	95
D	O	P	68	95
Inoculated control			55	86

The sprayings had no effect and the treated plants wilted just as rapidly as the inoculated plants that had not been treated. This is due to the fact that *F. oxysporum* penetrates the wood vessels and the fungicides give the plants only surface protection. The healthy control plants and the non-inoculated treated carnations remained healthy throughout the trial.

Since it was possible that systemic fungicides might protect the plants from the inside, a trial was arranged with these compounds. One batch of carnations was sprayed with fungicides 24 hours before soil inoculation with *F. oxysporum*, another batch 24 hours after. The systemic fungicides used were Benlate (1-(butylcarbamoyl)-2-benzimidazole carbamic acid, methyl ester 50 %), Plantvax (2,3-Dihydro-5-carboxanilido-6-methyl-1,4-oxathiin-4,4-dioxide) and Vitavax (2,3-Dihydro-5-carboxanilido-6-methyl-1,4-oxathiin), and in addition the non-systemic fungicide Pomarsol Forte (thiram 80 %). The results are presented below (a = advance control, b = subsequent control):

		Wilting percentage				
		26/3	2/4	4/4	14/4	21/4
Vitavax	a	0.0	21.4	67.9	82.1	92.9
»	b	0.0	25.0	60.7	89.3	96.4
Plantvax	a	7.2	78.6	96.4	96.4	100.0
»	b	3.6	75.0	96.4	100.0	100.0
Benlate	a	0.0	50.0	100.0	100.0	100.0
»	b	3.6	28.6	85.7	92.9	100.0
Pomarsol Forte	a	0.0	14.3	64.3	78.6	92.9
»	b	0.0	14.3	57.1	78.6	96.4
Inoculated control		0.0	42.9	78.6	92.9	92.9
Non-inoculated control		0.0	0.0	0.0	0.0	0.0

The systemic fungicides had no effect whatever, and within less than two months over 90 % of the treated plants and the inoculated non-treated plants had withered. The non-inoculated control was at the time completely healthy. There were no differences between the trial plants that had been sprayed 24 hours before and those sprayed 24 hours after the inoculation of the soil.

In another trial it was also planned to determine whether pre-planting treatment with fungicides would protect the cuttings from wilting disease. For this purpose rooted carnation cuttings were kept overnight in *F. oxysporum* suspension. Subsequently, some of the cuttings were placed in Benlate-solution and the other in Dithane M-45-solution for periods of varying length. After treatment, they were planted in the usual way. The following results were obtained:

Treatment	No. of plants	No. of wilted plants					
		26/2	17/3	24/3	29/3	8/4	21/4
Benlate 10 min.	6	1	3	5	6		
» 30 min	6	1	4	4	6		
» 60 min	6	1	2	6			
» 24 hours	6	0	0	0	0	3	5
Dithane M-45							
10 min	6	0	4	5	6		
» 60 min	6	0	0	0	6		
» 24 hours	6	0	0	1	3	6	
Untreated	11	0	11				

In the trial, all the treatments had somewhat delayed the onset of wilting. The untreated lot had wilted completely only one month after inoculation. At the time the plants that had received 24 hours' Benlate treatment and those that had had 60 minutes of Dithane M-45 treatment were completely healthy. While the plants that had been treated with Dithane M-45 for 24 hours had wilted completely in two months' time, of the plants that had been subjected to 24 hours' Benlate treatment, one half was still healthy. In conclusion, the spraying of rooted cuttings prior to planting with systemic fungicides and mancozeb-compound delayed wilting to a certain extent.

Summary

From 81 carnation samples collected in 1967—68 from nurseries in different parts of the country were identified 17 species of fungus, from a total of 177 fungus isolates. Among these, *Fusarium oxysporum* was most widespread, 31.1 %. *F. arthrosporioides*, *F. avenaceum*, *F. culmorum*, *Alternaria tenuis* and *Cladosporium* sp. occurred in considerable quantities. The percentage of *Phialophora cinerescens* was 1.1 %.

In the inoculation trials *F. oxysporum* behaved as a strongly pathogenic, infecting plants via the air through cut surfaces and via the soil by root-penetration. *A. tenuis*, *F. avenaceum* and *F. culmorum* infected carnations only from the air through cut surfaces.

In the fungicide trials against *F. oxysporum*, spraying the plants infected via the soil proved ineffective. The trials were made with the systemic Benlate (1-(butylcarbamoyl)-2-benzimidazole carbamic acid, methyl ester 50 %), Plantvax (2,3-Dihydro-5-carboxanilido-6-methyl-1,4-oxathiin-4,4-dioxide), Vitavax (2,3-Dihydro-5-caboxanilido-6-me-

thyl-1,4-oxathiin), and with the non-systemic Dithane M-45 (mancozeb 80 %), Orthocide 50 (captan 50 %) and Pomarsol Forte (thiram 80 %).

The dipping of rooted cuttings into Benlate and Dithane M-45 compounds to a certain extent delayed the process of wilting.

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SELOSTUS

SIENTEN AIHEUTTAMA NEILIKAN LAKASTUMISTAUTI SUOMESSA

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Vuosina 1967—68 tutkittiin Kasvitautien tutkimuslaitoksella neilikan lakastumistautia Suomessa, josta on esitetty alustavia tuloksia (RUOTSALAINEN 1969). Tutkimusta varten kerätyistä 81 neilikkanäytteesta määritettiin 17 sienilajia, yhteensä 177 sienieristyksestä. Näistä oli eniten *Fusarium oxysporum*ia, 31.1 %. Runsaasti oli myös *F. arthrosporioides*ta, *F. avenaceum*ia, *F. culmorum*ia, *Alternaria tenuis*ta ja *Cladosporium* sp:tä. *Phialophora cinerescens*iä oli 1.1 %.

Infektiokokeissa saastutti *F. oxysporum* voimakkaasti patogeenisena kasveja sekä maasta että ilmasta. *A. tenuis*, *F. avenaceum* ja *F. culmorum* saastuttivat neilikoita vain ilmasta haavapintojen kautta.

Fungisidiruiskutukset eivät tehonneet *F. oxysporum*ia vastaan tällä saastutetussa maassa kasvavissa neilikoissa. Kokeiltavina olivat systeemiset valmisteet Benlate (metyyli-1-(butyylikarbamoyyli)-2-bentsimidatsolikarbamaatti), Plantvax (2,3-dihydro-5-karboksianilido-6-metyyli-1,4-oksatiini-4,4-dioksidi) ja Vitavax (2,3-dihydro-5-karboksianilido-6-metyyli-1,4-oksatiini) sekä ei-systeemiset valmisteet Dithane M-45 (mankozebi), Orthocide 50 (kaptaani) ja Pomarsol Forte (tiraami).

Juurrutettujen pistokkaiden kastelu sekä Benlate- että Dithane M-45-valmisteella viivästytti jossain määrin lakastumista.