

Varietal resistance of lettuce to *Fusarium oxysporum* f. sp. *lactucae*

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Abstract

After the recent detection of serious losses caused by Fusarium wilt of lettuce, incited by *Fusarium oxysporum* f. sp. *lactucae*, in north-western Italy, thirty-two varieties of lettuce, belonging to different types and chosen among those typically grown in the affected area, were tested in order to evaluate the presence of field resistance to Fusarium wilt. Six experimental trials were carried out in glasshouse (4 trials) and growth chamber (2 trials). Roots of 15 day old plants were artificially inoculated by dipping in a spore suspension (1×10^6 CFU/ml) of the pathogen. One Italian isolate (FOL 4) and one American isolate (ATCC 76616) of *F. oxysporum* f. sp. *lactucae* were used. In the presence of a good level of disease incidence, a number of varieties, mostly belonging to the leaf lettuce type, were completely resistant to Fusarium wilt. All the tested varieties belonging to the butterhead and most of those belonging to the Batavia types were susceptible to the disease. In the case of the romaine selections, cultivar reaction ranged from susceptible to resistant. In all experiments, the Italian and USA isolates of *F. lactucae* behaved similarly on all the tested cultivars.

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1. Introduction

Fusarium wilt of lettuce, recently observed in Italy (Garibaldi et al., 2002), has emerged as a major production problem in Lombardy (north-western Italy), where every year repeated cropping of lettuce is carried out in the same soil. Symptoms were first observed on the cv Salad Bowl at thinning, when seedlings (30 day old) appeared wilted. Affected plants were stunted, and developed yellowed leaves and brown or black streaks in the vascular system.

A similar disease was described in Japan in 1967 (Matuo and Motohashi, 1967), the United States in 1993 (Hubbard and Gerik, 1993) and Taiwan (Huang and Lo, 1998). In Japan and Taiwan the causal agent was identified as *F. oxysporum* f. sp. *lactucae*, whereas in the USA the pathogen was described as *F. oxysporum* f. sp. *lactucum*. Most recently, Fusarium wilt was described in California coastal district (Grube et al., 2003). California and Italian isolates of *F. oxysporum* showed similar

pathogenicity as Japanese race 1 and it has been proposed that *F. oxysporum* f. sp. *lactucum* is identical to *F. oxysporum* f. sp. *lactucae* (M. Fujinaga, personal communication). Comparative taxonomic studies among different isolates of the pathogen isolated at different locations in the world are underway in our laboratory.

The classification based on morphological features in lettuce varieties includes seven horticultural types: crisphead, butterhead, romaine (or cos), leaf, stem, latin and oil-seed (Davis et al., 1997; Ryder, 1998). In Italy, as well as in the Mediterranean area, the lettuce types most frequently cultivated are romaine (also known as cos), butterhead and crisphead (Stravato, personal communication). A recent development within the lettuce industry is the production of lightly processed lettuce. Shredded or chopped lettuce is packaged in bulk for the restaurant trade and other institutions or in individual consumer salad packs. The latter were developed for a single-family meal and may contain lettuce alone or mixed with other salad vegetables. The soft-headed crisp types, known as Batavia and probably developed from leaf lettuce, are the most adapted for processed lettuce (Ryder, 1998). The recent outbreaks of Fusarium wilt in northern Italy occurred on spring and summer leaf

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lettuce, particularly on cultivars belonging to the Batavia type and grown for processed lettuce.

Fusarium wilt of lettuce is difficult to manage under intensive cropping systems, such as those adopted in the area infested with the disease in Italy. Soil disinfection is difficult to achieve for technical and economic reasons: steaming is too expensive, while available fumigants are not always applicable due to the intensive cropping adopted.

Since the pathogen can be transmitted by infected seeds (Garibaldi et al., 2004), is important to evaluate the variability existing among different isolates of the pathogen as well as the behaviour of different lettuce varieties.

The use of varieties with field resistance is an important approach in the management of Fusarium wilt: early studies carried out in the USA (Hubbard and Gerik, 1993) and Japan (Fujinaga et al., 2003) found differences in varietal response to this disease.

Little information is available in the literature concerning resistance to Fusarium wilt among varieties used for production in Italy.

The objective of this study was to identify lettuce varieties with field resistance from existing commercial

germplasm in order to provide useful information to local growers as well as to breeders, who could use this information to develop new lines or germplasm resistant to Fusarium wilt.

2. Materials and methods

2.1. Isolates used and their preservation

The Italian isolate FOL 4 of *Fusarium oxysporum* was obtained in 2002 from infected lettuce plants collected at Bergamo (north-western Italy). The isolate ATCC 76616 of *F. oxysporum* f. sp. *lactucum*, was obtained from the American Type Culture Collection (ATCC) and was isolated from infected plants in California (Hubbard and Gerik, 1993). The different strains were maintained on PDA at 8°C.

2.2. Production of inoculum

Strains FOL 4 and ATCC 76616 were grown in shake culture for 10 days on casein hydrolysate (0.2%) at 25°C with 12 h of fluorescent light per day. The culture

Table 1
List of lettuce varieties tested in the different trials

Code	Cultivar	Type	Seed company
3	Batavia	Batavia	Mazzocchi Sementi Srl
37	Batavia Camaro	Batavia	ISEA Spa
49	Batavia Funly tipe (S 0323)	Batavia	Sluis & Groot
2	Batavia gentilina bianca (sel. 1)	Batavia	Sluis & Groot
18	Grandi Laghi	Iceberg	Consorzio di Parma
11	Lattuga foglia di quercia rossa	Leaf lettuce	Graines Gautier
6	Salad bowd rossa amorina	Leaf lettuce	ISI Sementi Spa
4	Salad bowl	Leaf lettuce	Mazzocchi Sementi Srl
15	Salad bowl red	Leaf lettuce	Four Srl
24	Salad bowl	Leaf lettuce	Orosem
29	Salad bowl	Leaf lettuce	Olter Srl
23	Salad bowl red	Leaf lettuce	Four srl
30	Salad bowl red	Leaf lettuce	Olter Srl
17	Salad bowl red	Leaf lettuce	Consorzio di Parma
20	Regina di Maggio	Butterhead	Consorzio di Parma
19	Trocadero	Butterhead	Consorzio di Parma
35	Cappuccina Ballerina	Butterhead	ISEA Spa
9	Cappuccina Macre (Bra 1421)	Butterhead	Vilmorin Italia Srl
42	Cappuccio	Butterhead	Agridea Srl
32	Cappuccio Audran	Butterhead	Sluis & Groot
33	Cappuccio Lido RS	Butterhead	Royal Sluis Italia Spa
43	Cappuccio Nun 0008	Butterhead	Sementi Nunhems Srl
38	Cappuccio Serena	Butterhead	Olter Srl
36	Catalogna Barba dei frati	Chicory	Quadrisem
21	Romana	Romaine	Four Srl
46	Romana	Romaine	Agridea Srl
12	Romana roma Gaillarde	Romaine	Graines Gautier
41	Romana Blonde Lenta	Romaine	Vilmorin Italia Srl
39	Romana Capistrano	Romaine	Peto Italiana Srl
44	Romana Imperator	Romaine	Peto Italiana Srl
40	Romana Odessa	Romaine	Sluis & Groot
34	Romana Velvet	Romaine	Enza Zaden

suspension was then filtered through one layer of cheese cloth. The concentration of spores and mycelium fragments was determined by hemacytometer and adjusted with deionized water to 1×10^6 CFU (colony forming units)/ml.

2.3. Susceptibility test

Thirty-two lettuce varieties were tested, including those typically grown in the affected area as well as a wide range of cultivars produced by different seed

Table 2

Reaction of several lettuce cultivars and lines inoculated with the Italian (I) and American (USA) isolates of *Fusarium oxysporum* f. sp. *lactucae*. Trial 1 (Transplant in glasshouse: July 29, 2002; End of trial: August 19, 2002)

Code	Cultivar/line (seed company)	% wilted (dead) plants after days					
		8		15		22	
		I	USA	I	USA	I	USA
3	Batavia (Mazzocchi Sementi srl)	33	39	76	50	76 cde ^a	72 bcd
2	Batavia gentilina bianca (sel. 1) (Sluis & Groot)	14	24	33	24	48 bcd	38 abc
9	Cappuccina Macre (Bra 1421) (Vilmorin Italia Srl)	17	28	67	67	78 cde	83 cd
11	Lattuga foglia di quercia rossa (Graines Gautier)	44	39	56	50	100 e	100 d
12	Romana roma Gaillarde (Graines Gautier)	17	0	33	50	100 e	83 bcd
6	Salad bowd rossa amorina (ISI)	0	0	0	0	0 a	0 a
4	Salad bowl (Mazzocchi Sementi srl)	0	0	33	39	33 abc	39 abc
15	Salad bowl red (Four Srl)	0	0	0	0	0 a	0 a
18	Grandi Laghi (Consorzio di Parma)	15	10	15	10	40 abc	40 ab
20	Regina di maggio (Consorzio di Parma)	0	0	50	67	67 bcde	67 bcd
17	Salad Bowl rossa (Consorzio di Parma)	0	0	0	0	0 a	0 a
19	Trocadero (Consorzio di Parma)	0	0	30	35	40 abc	35 abc

^aMeans within a column, followed by the same letter, do not significantly differ following Tukey's Test ($P = 0.05$).

Table 3

Reaction of several lettuce cultivars and lines inoculated with the Italian (I) and American (USA) isolates of *Fusarium oxysporum* f. sp. *lactucae*. (Trial 2; Transplant in glasshouse: August 23, 2002; End of trial: September 17, 2002)

Code	Cultivar/line (seed company)	% wilted plants at days after transplant					
		10		18		25	
		I	USA	I	USA	I	USA
37	Batavia Camaro (ISEA Spa)	0	0	0	0	8 ab ^a	12 ab
49	Batavia Funly tipe (S 0323) (Sluis & Groot)	0	0	46	75	83 defg	79 cde
35	Cappuccina Ballerina (ISEA Spa)	12	25	100	100	100 g	100 e
42	Cappuccio (Agridea)	0	0	58	71	96 fg	96 e
32	Cappuccio Audran (Sluis & Groot)	4	8	96	100	96 fg	100 e
33	Cappuccio Lido RS (Royal Sluis Italia Spa)	54	42	100	100	100 g	100 e
43	Cappuccio Nun 0008 (Sementi Nunhems Srl)	25	42	100	100	100 g	100 e
38	Cappuccio Serena (Olter Srl)	0	0	0	0	87 defg	87 defg
36	Catalogna Barba dei frati (Quadrisem)	0	0	0	0	0 a	0 a
21	Romana (Four Srl)	25	8	83	71	92 efg	92 de
46	Romana (Agridea)	0	0	62	67	62 def	67 cd
41	Romana Blonde Lenta (Vilmorin Italia Srl)	0	0	0	0	12 abc	8 a
39	Romana Capistrano (Peto Italiana Srl)	0	0	0	0	25 bc	29 bc
44	Romana Imperator (Peto Italiana Srl)	0	0	0	0	8 abc	4 a
31	Romana Lisa (Peto Italiana Srl)	0	0	25	4	54 cde	46 bc
40	Romana Odessa (Sluis & Groot)	0	0	37	54	92 efg	92 de
34	Romana Velvet (Enza Zadem)	0	0	0	0	92 efg	92 de
24	Salad bowl (Orosema Spa)	46	42	79	87	96 fg	92 de
29	Salad bowl (Lollo Bionda) (Olter Srl)	0	0	4	0	4 ab	8 a
23	Salad bowl red (Four Srl)	0	0	0	0	0 a	0 a
30	Salad bowl red (Lollo rossa) (Olter Srl)	12	4	12	4	12 abc	8 a

^aMeans of the same column, followed by the same letter, do not significantly differ following Tukey's test ($P = 0.05$).

companies (Table 1). Seeds were planted in a steamed soil mixture (peat, compost broadleaf bark and clay, respectively, 60:20:20 vol/vol) in plug trays and maintained at 25°C. Roots of 15-day-old plants were washed, trimmed to a length of 5 cm, and dipped for 10 min in the pathogen spore suspension prepared as described above. Inoculated seedlings were then transplanted into steamed soil (30 min at 70°C) in containers (10 l volume). Control plants were prepared similarly but soaked in plain deionized water. Sixteen seedlings per container were transplanted in the different trials. Each container was considered one replicate. Three replicates were used. A total of six trials was carried out: four under glasshouse conditions and two in a growth chamber. A completely randomized block design was used. Plants were maintained in a glasshouse at temperatures ranging from 15°C (min) to 27°C (max) in trials 1, 2, 3 and 6 and in a growth chamber (25°C, with 12 h of fluorescent light per day) in trials 4 and 5. Symptoms started to be visible 8–13 days after artificial inoculation. Plants were evaluated weekly for disease development and wilted plants were counted. The data

are expressed as percent of dead plants at three different ratings. The final disease rating took place 3–5 weeks after inoculation. Most varieties were tested at least three times.

In the case of the last rating, percentage data were analyzed statistically using analysis of variance and Tukey's test.

3. Results

The method of artificial inoculation adopted resulted in good levels of disease incidence in all trials, proving useful for screening for *Fusarium* wilt resistance. The tested varieties (Table 1) provided consistent results in the different trials. In the case of highly susceptible varieties, wilt developed very quickly, particularly under growth chamber conditions. In all the trials (Tables 2–7) the Italian and USA isolates showed similar development of disease among tested cultivars.

A number of varieties ("Salad Bowl red", code 6,15,17, Table 2; "Salad bowl red" 23, Table 3; "Salad

Table 4

Reaction of several lettuce cultivars and lines inoculated with the Italian (I) and American (USA) isolates of *Fusarium oxysporum* f. sp. *lactucae*. (Trial 3; Transplant in glasshouse: November 5, 2002; End of trial: December 18, 2002)

Code	Cultivar (seed company)	% of wilted plants at days after transplant					
		28		36		43	
		I	USA	I	USA	I	USA
37	Batavia Camaro (ISEA Srl)	20	20	20	20	20 abc ^a	20 abc
49	Batavia Funly tipe (S 0323) (Sluis & Groot)	10	10	10	10	40 bcd	40 bcd
2	Batavia gentilina bianca (sel. 1) (Sluis & Groot)	60	60	80	80	100 f	80 efg
35	Cappuccina Ballerina (ISEA Srl)	60	60	60	100	80 ef	100 g
9	Cappuccina Macre (Bra 1421) (Vilmorin Italia Srl)	80	80	100	100	100 f	100 g
42	Cappuccio (Agridea)	0	0	50	70	60 cde	90 fg
32	Cappuccio Audran (Sluis & Groot)	50	50	90	100	100 f	100 g
33	Cappuccio Lido RS (Royal Sluis Italia Spa)	90	90	100	100	100 f	100 g
43	Cappuccio Nun 0008 (Sementi Nunhems Srl)	90	90	90	100	100 f	100 g
38	Cappuccio Serena (Olter Srl)	30	30	80	100	100 f	100 g
36	Catalogna Barba dei frati (Quadrisem)	0	0	0	0	0 a	0 a
18	Grandi Laghi (Consorzio di Parma)	10	10	40	20	40 bcd	60 def
11	Lattuga foglia di quercia rossa (Graines Gautier)	75	75	100	100	100 f	100 g
20	Regina di Maggio (Consorzio di Parma)	0	0	0	0	50 cde	60 def
21	Romana (Four Srl)	30	30	40	50	40 bcd	50 cde
46	Romana (Agridea)	30	30	60	100	80 ef	100 g
41	Romana Blonde Lenta (Vilmorin Italia Srl)	0	0	0	0	0 a	0 a
39	Romana Capistrano (Peto Italiana Srl)	0	0	0	0	0 a	0 a
44	Romana Imperator (Peto Italiana Srl)	0	0	0	0	0 a	0 a
31	Romana Lisa (Peto Italiana Srl)	0	0	20	10	40 bcd	20 abc
40	Romana Odessa (Sluis & Groot)	0	0	80	100	100 f	100 g
34	Romana Velvet (Enza Zaden)	0	0	0	30	60 cde	80 def
24	Salad bowl (Orosema Spa)	50	50	80	80	80 de	90 fg
29	Salad bowl (Lollo Bionda) (Olter Srl)	0	0	0	20	20 abc	20 abc
23	Salad bowl red (Four Srl)	0	0	0	0	10 ab	0 a
30	Salad bowl red (Lollo rossa) (Olter Srl)	0	0	0	10	0 a	10 ab
17	Salad bowl rossa (Consorzio di Parma)	0	0	10	0	10 ab	0 a
19	Trocadero (Consorzio di Parma)	0	0	10	30	40 bcd	80 def

^aMeans of the same column, followed by the same letter, do not significantly differ following Tukey's test ($P = 0.05$).

Table 5

Reaction of several lettuce cultivars and lines inoculated with the Italian (I) and American (USA) isolates of *Fusarium oxysporum* f. sp. *lactucae*. (Trial 4; Transplant in growth chamber: December 12, 2002; End of trial: January 7, 2003)

Code	Cultivar (seed company)	% of wilted plants at days after transplant					
		8		15		36	
		I	USA	I	USA	I	USA
37	Batavia Camaro (ISEA Srl)	0	25	0	25	0 a ^a	25 b
49	Batavia Funly tipe (S 0323) (Sluis & Groot)	25	0	50	50	100 d	100 c
2	Batavia gentilina bianca (sel. 1) (Sluis & Groot)	50	50	100	100	100 d	100 c
9	Cappuccina Macre (Bra 1421) (Vilmorin Italia Srl)	50	75	100	100	100 d	100 c
42	Cappuccio (Agridea)	75	100	100	100	100 d	100 c
33	Cappuccio Lido RS (Royal Sluis Italia Spa)	100	100	100	100	100 d	100 c
38	Cappuccio Serena (Olter Spa)	50	100	100	100	100 d	100 c
36	Catalogna Barba dei frati (Quadrisem)	0	0	10	0	8 ab	0 a
18	Grandi Laghi (Consorzio di Parma)	100	100	100	100	100 d	100 c
20	Regina di Maggio (Consorzio di Parma)	100	67	100	100	100 d	100 c
21	Romana (Four Srl)	100	50	100	100	100 d	100 c
46	Romana (Agridea)	50	75	50	75	100 d	100 c
41	Romana Blonde Lenta (Vilmorin Italia Srl)	50	50	100	100	100 d	100 c
39	Romana Capistrano (Peto Italiana Srl)	0	0	25	0	25 bc	25 ab
44	Romana Imperator (Peto Italiana Srl)	100	100	100	100	100 d	100 c
31	Romana Lisa (Peto Italiana Srl)	100	100	100	100	100 d	100 c
40	Romana Odessa (Sluis & Groot)	50	50	50	100	50 c	100 c
34	Romana Velvet (Enza Zaden)	50	25	100	25	100 d	75 c
24	Salad bowl (Orosem Spa)	100	100	100	100	100 d	100 c
29	Salad bowl (Lollo Bionda) (Olter Srl)	33	0	50	33	50 c	33 b
23	Salad bowl red (Four Srl)	0	0	0	0	0 a	0 a
30	Salad bowl red (Olter Srl)	0	0	0	0	0 a	33 b
17	Salad bowl red (Consorzio di Parma)	0	0	0	0	0 a	0 a
19	Trocadero (Consorzio di Parma)	25	25	100	100	100 d	100 c

^aMeans of the same column, followed by the same letter, do not significantly differ following Tukey's test ($P = 0.05$).

Table 6

Reaction of several lettuce cultivars and lines inoculated with the Italian (I) and American (USA) isolates of *Fusarium oxysporum* f. sp. *lactucae*. (Trial 5; Transplant in growth chamber: January 31, 2003; End of trial: March 10, 2003)

Code	Cultivar (seed company)	% of wilted plants at days after transplant					
		8		15		36	
		I	USA	I	USA	I	USA
9	Cappuccina Macre (Bra 1421) (Vilmorin Italia Srl)	100	100	100	100	100 b ^a	100 b
42	Cappuccio (Agridea)	100	100	100	100	100 b	100 b
20	Regina di Maggio (Consorzio di Parma)	0	50	50	75	100 b	100 b
21	Romana (Four Srl)	0	50	50	75	100 b	100 b
46	Romana (Agridea)	50	100	100	100	100 b	100 b
29	Salad bowl (Lollo Bionda) (Olter Srl)	0	0	100	100	100 b	100 b
23	Salad bowl red (Four Srl)	0	0	0	0	0 a	0 a
17	Salad bowl red (Consorzio di Parma)	0	0	0	0	8 a	0 a
19	Trocadero (Consorzio di Parma)	50	0	100	75	100 b	100 b

^aMeans of the same column, followed by the same letter, do not significantly differ following Tukey's test ($P = 0.05$).

Bowl red" 17, "Romana Blonde Lenta" 41, "Romana Capistrano" 39, "Romana Imperator" 44, Table 4; "Salad Bowl red" 23 and 17, Table 5; "Salad Bowl red" 23, Table 6) were completely resistant to Fusarium wilt. Other varieties, such as "Batavia Camaro" 37 can be classified as at least partially resistant (Tables 3–5 and 7).

All the tested varieties belonging to the butterhead type (Table 1) were susceptible to the disease.

In the case of romaine type selections, cultivar reaction to Fusarium wilt ranged from susceptible to resistant (Table 8). Among the tested varieties belonging to the Batavia type, only the variety Batavia Camaro demonstrated a partial resistance to Fusarium wilt (Tables 3–5, 7 and 8). The cv Batavia gentilina bianca, which is highly desirable commercially, demonstrated an average to high susceptibility to the disease (Tables 2, 4, 5, 7 and 8).

Table 7

Reaction of several lettuce cultivars and lines inoculated with the Italian (I) and American (USA) isolates of *Fusarium oxysporum* f. sp. *lactucae*. (Trial 6; Transplant in glasshouse: April 4, 2003; End of trial: May 7, 2003)

Code	Cultivar (seed company)	% wilted plants after days					
		13		20		27	
		I	USA	I	USA	I	USA
37	Batavia Camaro (ISEA Srl)	0	0	0	0	0 a ^a	0 a
49	Batavia Funly tipe (S 0323) (Sluis & Groot)	0	0	30	0	40 bc	40 bc
2	Batavia gentilina bianca (sel. 1) (Sluis & Groot)	27	20	67	57	67 bcd	57 bcde
9	Cappuccina Macre (Bra 1421) (Vilmorin Italia Srl)	67	60	90	80	90 ef	80 e
32	Cappuccio Audran (Sluis & Groot)	100	100	100	100	100 f	100 f
33	Cappuccio Lido RS (Royal Sluis Italia Spa)	20	20	70	63	73 bcde	63 cde
38	Cappuccio Serena (Olter Spa)	25	35	43	63	80 cde	70 cde
43	Cappuccio Nun 0008 (Sementi Nunhems Srl)	100	100	100	100	100 f	100 f
36	Catalogna Barba dei frati (Quadrisem)	0	0	0	0	0 a	0 a
18	Grandi Laghi (Consorzio di Parma)	0	0	33	27	33 b	27 b
20	Regina di Maggio (Consorzio di Parma)	0	0	37	33	47 bc	50 bcd
21	Romana (Four Srl)	47	27	47	35	57 bcd	47 bcd
46	Romana (Agridea)	70	40	80	63	90 def	80 de
41	Romana Blonde Lenta (Vilmorin Italia Srl)	0	0	0	0	0 a	0 a
39	Romana Capistrano (Peto Italiana Srl)	0	0	0	0	0 a	0 a
44	Romana Imperator (Peto Italiana Srl)	0	0	0	0	0 a	0 a
31	Romana Lisa (Peto Italiana Srl)	0	0	0	0	0 a	0 a
40	Romana Odessa (Sluis & Groot)	53	33	73	60	80 cde	77 cde
34	Romana Velvet (Enza Zaden)	47	40	67	67	67 cde	67 cde
24	Salad bowl (Oroseum Spa)	37	40	67	73	67 f	73 f
29	Salad bowl (Lollo Bionda) (Olter Srl)	0	0	0	0	0 a	0 a
23	Salad bowl red (Four Srl)	0	0	0	0	0 a	0 a
30	Salad bowl red (Olter Srl)	0	0	0	0	0 a	0 a
17	Salad bowl red (Consorzio di Parma)	0	0	0	0	0 a	0 a
19	Trocadero (Consorzio di Parma)	0	0	3	3	40 bc	47 bcd

^aMeans of the same column, followed by the same letter, do not significantly differ following Tukey's test ($P = 0.05$).

4. Discussion

Yamauchi et al. (2001) divided isolates of *Fusarium oxysporum* f. sp. *lactucae* obtained from six locations in Japan into three pathogenicity groups: group 1 was highly pathogenic to lettuce cultivars of crisphead and red leaf types and less pathogenic to butterhead and green leaf type cultivars; group 2 was highly pathogenic to the butterhead type and less pathogenic to crisphead and leaf types; group 3 was less pathogenic to all lettuce types compared to groups 1 and 2.

Fujinaga et al. (2001) who described the presence of two races (1 and 2) of *F. oxysporum* f. sp. *lactucae*, obtained from separate major lettuce-producing areas in Nagano, recently reported the presence of a third race (race 3) (Fujinaga et al., 2003). The Italian isolate of *F. oxysporum* f. sp. *lactucae* used in this study has been identified by pathogenicity tests conducted by M. Fujinaga (personal communication) as race 1, similar to the USA isolate. Actually, in our experiments the Italian and USA isolates of *F. oxysporum* behaved similarly on all the tested cultivars.

Resistance trials carried out in the USA, showed that all tested cultivars had some susceptibility to

Fusarium wilt. Among the lettuce cultivars most popular in the USA, Salinas was most tolerant, while "Vanguard", "Vanguard 75" and "Vanmax" were the most susceptible (Hubbard and Gerik, 1993). More recently, Grube et al. (2003) confirmed the susceptibility of the "Vanguard" and "Empire" type cultivars, while the "Salinas 88" type of varieties, although not immune to the pathogen, exhibited a high level of resistance.

Some of the varieties of lettuce tested in Italy were completely resistant to *Fusarium* wilt. It is interesting to observe that most of the resistant varieties are leaf lettuce ("Salad bowl red") or romaine types of lettuce. However, among leaf and romaine lettuce, not all the selections of "Salad bowl" tested were resistant to *Fusarium* wilt. Some of the varieties of lettuce showing resistance to *Fusarium* wilt are of commercial interest, not only in Italy but also in other areas were lettuce for processing is increasingly cultivated. For instance, the cvs Salad Bowl red (code 15, 23, 30, 17) are valuable for processed lettuce. However, among the tested varieties belonging to the Batavia type, only one ("Batavia Canasta") was partially resistant to *Fusarium* wilt.

Table 8
Reaction of the tested cultivars to the Italian (I) and American (USA) isolates of *Fusarium oxysporum* f. sp. *lactucae* in the different trials

Code	Cultivar (seed company)	Glasshouse						Growth chamber									
		1st		2nd		3rd		6th		4th		5th					
		I	USA	I	USA	I	USA	I	USA	I	USA	I	USA				
3	Batavia (Mazzocchi Sementi Srl)	S ^a	S														
37	Batavia Camaro (ISEA Srl)			R	R	PR	PR	R	R	R	PR						
49	Batavia Funly tipe (S 0323) (Sluis & Groot)			S	S	AS	AS	AS	AS	S	S						
2	Batavia gentilina bianca (sel. 1) (Sluis & Groot)	AS	AS			S	S	S	S	S	S						
35	Cappuccina Ballerina (ISEA)			S	S	S	S										
9	Cappuccina Macre (Bra 1421)(Vilmorin Italia Srl)	S	S			S	S	S	S	S	S	S	S	S	S	S	S
42	Cappuccio (Agridea)			S	S	AS	S			S	S	S	S	S	S	S	S
32	Cappuccio Audran (Sluis & Groot)			S	S	S	S	S	S								
33	Cappuccio Lido RS (Royal Sluis Italia Spa)			S	S	S	S	S	S	S	S						
43	Cappuccio Nun 0008 (Sementi Nunhems Srl)			S	S	S	S	S	S								
38	Cappuccio Serena (Olter Srl)			S	S	S	S	S	S	S	S						
36	Catalogna Barba dei frati (Quadrisem)			R	R	R	R	R	R	R	R						
18	Grandi Laghi (Consorzio di Parma)	AS	AS			AS	AS	AS	AS	S	S						
11	Lattuga foglia di quercia rossa (Graines Gautier)	S	S			S	S										
20	Regina di Maggio (Consorzio di Parma)	S	S			S	S	AS	AS	S	S	S	S	S	S	S	S
21	Romana (Four)			S	S	AS	AS	AS	AS	S	S	S	S	S	S	S	S
46	Romana (Agridea)			S	S	S	S	S	S	S	S	S	S	S	S	S	S
12	Romana roma Gaillarde (Graines Gautier)	S	S														
41	Romana Blonde Lenta (Vilmorin Italia Srl)			PR	R	R	R	R	R	S	S						
39	Romana Capistrano (Peto Italiana Srl)			PR	PR	R	R	R	R	PR	PR						
44	Romana Imperator (Peto Italiana Srl)			R	R	R	R	R	R	S	S						
31	Romana Lisa (Petoseed)			AS	AS	AS	PR	R	R	S	S						
40	Romana Odessa (Sluis & Groot)			S	S	S	S	S	S	AS	S						
34	Romana Velvet (Enza Zadem)			S	S	AS	S	S	S	S	S						
6	Salad bowd rossa amorina (ISI)	R	R														
4	Salad bowl (Mazzocchi Sementi Srl)	AS	AS														
15	Salad bowl red (Four Srl)	R	R														
24	Salad bowl (Oroseem Spa)			S	S	S	S	S	S	S	S						
29	Salad bowl (Lollo Bionda) (Olter Srl)			R	R	PR	PR	R	R	AS	AS	S	S	S	S	S	S
23	Salad bowl red (Four Srl)			R	R	R	R	R	R	R	R	R	R	R	R	R	R
30	Salad bowl red (Lollo rossa) (Olter Srl)			R	R	R	R	R	R	R	AS						
17	Salad bowl rossa (Consorzio di Parma)	R	R			R	R	R	R	R	R	R	R	R	R	R	R
19	Trocadero (Consorzio di Parma)	AS	AS			AS	S	AS	AS	S	S	S	S	S	S	S	S

^aR=resistant (Disease Index 1–10); PR=partially resistant (Disease Index 11–30); AS=averagely susceptible (Disease Index 31–60); S=Susceptible (Disease Index 61–100).

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