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Epidemiology of esca in some vineyards in Tuscany (Italy)

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Summary. The incidence of esca in 5 vineyards (SCFI, GTFI, CBSI-1, 2, 3) in Tuscany was monitored from 1992 to 1994 in SCFI, from 1993 to 1998 in GTFI, and from 1995 to 1998 in CBSI-1, 2 and 3. Disease incidence varied from vineyard to vineyard and from year to year. SCFI was the vineyard most affected with an incidence of 63% in 1993, 20% in 1994, and 46% in 1992. However, symptom expression in individual plants was characterized by very marked discontinuity from year to year. As a result, only 8% of diseased plants in SCFI had foliar symptoms in all 3 years of the survey period. The percentage of consistently diseased plants went down to less than 1% in GTFI and CBSI-3 and was nil in CBSI-1 and 2. The cumulative disease incidence, calculated by counting all the plants that showed foliar symptoms at least once in the years surveyed, was 82, 50, 19, 12, and 10% in SCFI, GTFI, CBSI-3, 1 and 2 respectively. An examination of rainfall and air temperature parameters in relation to esca incidence did not detect any weather conditions especially conducive to esca. However, it seemed that a fresh, rainy summer is more favorable to the chronic form of esca while a hot, dry summer is more conducive to the acute form.

Key words: grapevine, esca, epidemiology.

Introduction

Esca (esca proper, sensu Graniti *et al.*, 1999), an important disease of grapevine in many parts of the world, is caused by at least two or three fungi, *Phaeoacremonium aleophilum*, *P. chlamydosporum* and *Fomitiporia punctata*, acting in combination or in succession (Larignon and Dubos, 1977; Mugnai *et al.*, 1999; Graniti *et al.*, 1999). Grape growers suffer the death of numerous plants every year as well as a loss of production. Moreover, the life of vineyards is much reduced.

Esca-diseased vines may show both external and internal symptoms (reviewed in Mugnai *et al.*, 1999). External symptoms consist in light green to chlorotic turning into necrotic spots between the veins and/or along the leaf margins (chronic esca). In the trunk the most common symptoms are: dark brown streaks, visible as spots in cross section, thinly scattered through the wood or clustered in small groups; brown areas, often connected with large wounds; pink-brown or dark red-brown areas, often on the margin of decayed or necrotic tissues; and white rot, which reduces the wood to a light-coloured spongy mass. Sometimes diseased grapevines wilt suddenly (apoplexy or acute esca).

External symptoms of esca are clearly visible in summer, but a remarkable characteristic of the disease is the unpredictable discontinuity in foliar symptom expression from year to year (Hewitt, 1957; Mugnai *et al.*, 1996). More recently it has been reported (Mugnai *et al.*, 1999) that

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in a 4-year survey of a vineyard in Tuscany, only about 3% of diseased plants exhibited foliar esca symptoms consistently in all 4 years in succession; 11.5% of plants had symptoms in any 3 years out of 4, 23% in any 2 years out of 4, and 53% in any 1 year out of 4. Although no investigations into the cause of this discontinuity were carried out, the Authors suggested that environmental and seasonal factors could have been the reason.

The present report describes in greater detail the varying pattern of foliar symptom expression of esca-diseased vines from year to year in five vineyards at three locations in Tuscany. And because almost nothing is known about the weather conditions that may favor the appearance of leaf esca symptoms or of apoplexy, we also looked for a relation among rainfall, temperature and esca symptom expression on grapevines in Tuscany.

Materials and methods

The spread of esca was monitored in five vineyards: two in the province of Florence, at San Casciano Val di Pesa (SCFI) and at Gambassi Terme (GTFI), and three in the province of Siena at Castelnuovo Berardenga (CBSI-1, 2 and 3). These last three were experimental vineyards contiguous to each other, planted by the "Dipartimento di Ortoflorofrutticoltura" of the University of Florence to study the agronomic performance of two grape cultivars, Sangiovese and Trebbiano Toscano, grafted onto 5 different rootstocks, as well as that of 17 white grape cultivars. The main characteristics of the 5 vineyards are listed in Table 1.

During the summer of each year from 1992 to 1998, a block of vines was surveyed in each vineyard. SCFI was surveyed in 1992, 1993 and 1994, CBSI-1, 2 and 3 from 1995 to 1998 and GTFI from 1993 to 1998. Generally two surveys per year were carried out, one in July and one in September, but in 1996, 1997 and 1998 the number of surveys in GTFI was increased to 7 in 1996 (3 in July, 3 in August and 1 in September), 8 in 1997 (1 in June, 2 in July, 3 in August, 2 in September) and 6 in 1998 (1 in June, 3 in July, 1 in August, 1 in September). A further survey was done in CBSI-1, 2 and 3 and in GTFI at the start of spring every year to identify those vines that did not revegetate. These vines were uprooted the following winter and were deemed to have died from apoplexy if they had presented acute or chronic esca symptoms in at least one year before they died, or if there was no other possible cause of death, such as *Armillaria mellea* or *Verticillium dahliae* infection. At each survey all vines were examined for external esca symptoms and visually rated on a scale based on the percentage of leaves with symptoms and the presence of wilting symptoms on leaves and bunches: 1, 1-10% of leaves with symptoms; 2, 10-30%; 3, 30-70%; 4, more than 70% of leaves with symptoms and completely or partially wilted bunches; 5, plant completely wilted (apoplexy).

For each vineyard and year a two-dimensional map was generated showing the esca health status of all vines. Moreover, for each year after the first a cumulative map was also generated which not only marked all vines with external symptoms in the current year, but also all those that had had symptoms in any previous year or years.

Temperature and rainfall data from weather stations (WS) near the vineyards were utilized to relate weather data to disease incidence. At Gambassi Terme the WS was located within 50 m of the plot in which the disease assessments were made. At Castelnuovo Berardenga it was less than 900 m from the 3 vineyards. For San Casciano Val di Pesa the weather data were the average of 6 WSs located around the vineyard at distances varying from 3 to 15 km in a linear direction.

Results and discussion

Disease discontinuity in individual plants

Esca was detected in all vineyards (Tables 2, 3, and 4). Diseased plants showed foliar symptoms varying in intensity from 1 to 4, and, less frequently, wilt symptoms involving the whole plant (apoplexy).

At San Casciano Val di Pesa incidence of esca was high in 1993 (63.37%), intermediate in 1992 (46.43%) and low in 1994 (19.62%). Figure 1 maps all the vines in the vineyard for each of the years surveyed, showing vacancies and vines with and without esca symptoms. In 1992 there were already 553 vacancies, or 47.8% of the initial total of 1156 plants in this vineyard, demonstrating its serious degradation even before the survey started, probably because of esca. In that year, out of the 603 vines that remained standing, 277 plants showed the external symptoms of esca. In 1993 there were

Table 1. Characteristics of five vineyards surveyed for esca. (For explanation of acronyms refer to text).

Characteristic	Vineyard				
	SCFI	GTFI	CBSI-1	CBSI-2	CBSI-3
No. of vines per vineyard	603	545	512	532	1155
Year planted	1971	1970	1982	1982	1982
Slope	8%	5-15%	15%	15%	15%
Orientation of the vineyard columns	S/W	E/W	N/W	N/W	N/W
Vine spacing	2.8x1.2m	2.8x1.2m	2.8x1.4m	2.8x1.4m	2.8x1.4m
Training	Controspalliera	Controspalliera	Controspalliera	Controspalliera	Controspalliera
Pruning	Capovolto	Capovolto	Guyot	Guyot	Guyot
Altitude	100-150m	330m	350-450m	350-450m	350-450m
Cultivar(s)	Sangiovese Canaiolo Nero Colorino	Sangiovese, Trebbiano T.	Sangiovese	Trebbiano T.	Various[a]
Rootstock(s)	?	?	Various[b]	Various[b]	140Ru

[a] Seventeen cultivars in the block, one cv. per column, 19 columns: 1, Trebbiano toscano; 2, Malvasia bianca; 3, Pinot bianco; 4, Pinot grigio; 5, Riesling italico; 6, Riesling renano; 7, Sauvignon; 8, Verdicchio; 9, Incrocio Base 51; 10, Incrocio 6013; 11, Pinot bianco;12, Malvasia istriana; 13, Chardonnay; 14, Vermentino bianco; 15, Canaiolo bianco; 16, Moscato bianco; 17, Semmillion; 18, Roussanne; 19, Chardonnay.
[b] Five rootstocks: 140Ru; K5BB; SO4; 420A; 1103P and self-rooted plants, randomly distributed through the vineyard.

Table 2. Incidence of esca in a vineyard at San Casciano Val di Pesa (Florence), from 1992 to 1994.

Vineyard	Year	No. of standing plants	No. of symptomatic plants	September esca incidence %
SCF1	1992	603	277[a] (553)[b]	46.43
	1993	557	353[a] (44*+3**)[c]	63.37
	1994	535	105[a] (18*+4**)[c]	19.62
	1993 + ('92)	603	466[d]	77.28
	1994 + ('92+'93)	603	496[d]	82.25

[a] Vines with external symptoms in the year indicated.
[b] Plants missed before 1992.
[c] In parentheses is given the number of symptomatic (*) and asymptomatic (**) vines that did not revegetate in the spring of the current year. These plants were uprooted and are marked with a "V" on the map in Figure 1.
[d] Vines which showed external symptoms for the first time in the year indicated plus all vines which had shown external symptoms in any previous year(s).

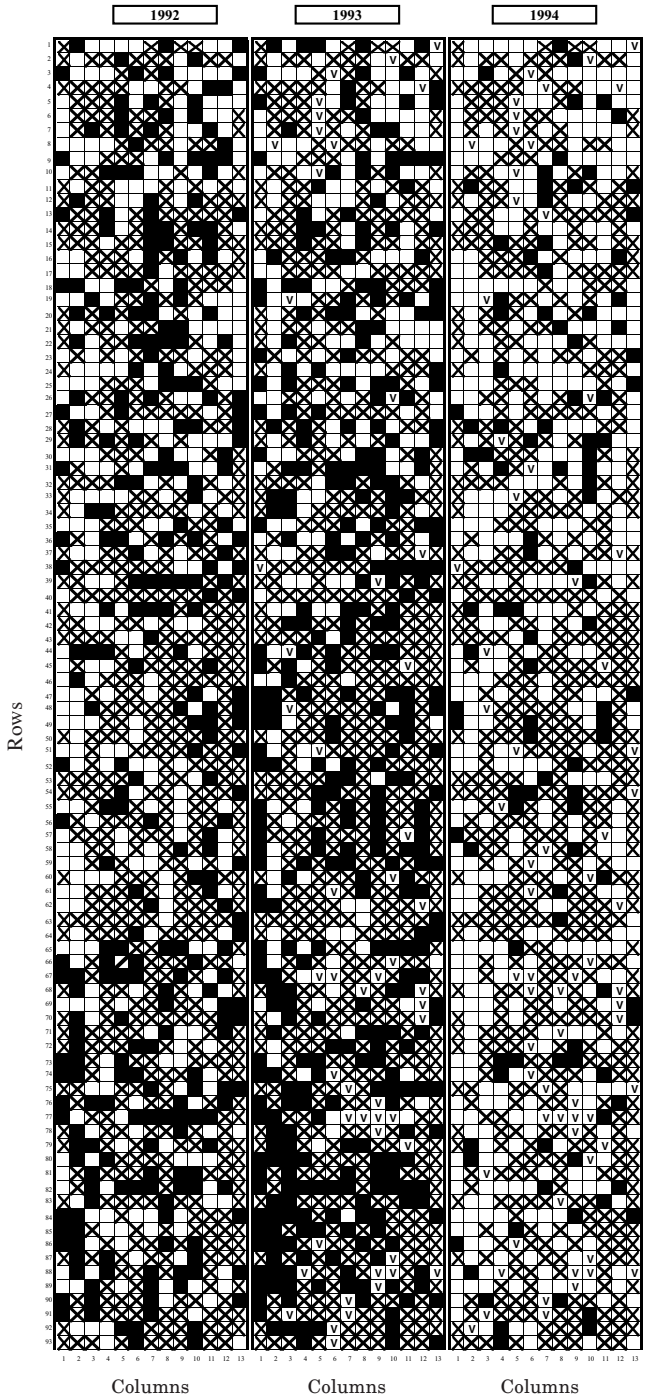

Fig. 1. Annual spatial pattern of esca-diseased plants in a vineyard at San Casciano Val di Pesa in the province of Florence. Black squares, symptomatic plants; open squares, asymptomatic plants; "**X**", plants died before start of survey (cause unknown); "**V**", plants died during survey period, with or without esca symptoms in the previous year.

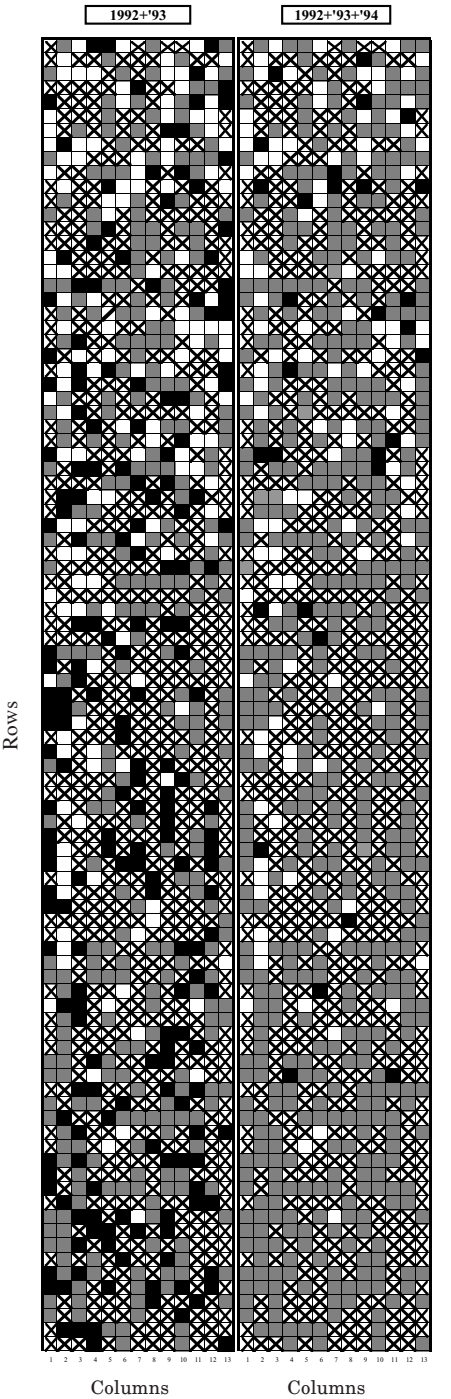

Fig. 2. Spatial pattern of esca-diseased plants in a vineyard at San Casciano Val di Pesa in the province of Florence cumulated. Black squares, symptomatic plants; open squares, asymptomatic plants; gray squares, symptomatic plants in previous years, or dead; "**X**", plants died before start of survey (cause unknown).

Table 3. Incidence of esca in a vineyard at Gambassi Terme (Florence), from 1993 to 1998.

Year	No. of standing plants	No. of symptomatic plants	No. of apopletic plants	No. of plants that did not revegetate in the spring of the year indicated	September esca incidence (%)
1993	545	86[a]	17	14[b]	15.96
1994	535	85[a]	18	10 (9*+1**)[c]	16.82
1995	522	57[a]	15	13 (8*+5**)[c]	11.11
1996	516	92[a]	18	6 (5*+1**)[c]	18.60
1997	491	79[a]	14	25 (21*+4**)[c]	11.20
1998	483	78[a]	14	8 (7*+1**)[c]	12.83
1994 + ('93)	545	145[d]	35		26.60
1995 + ('93+'94)	545	182[d]	50		33.40
1996 + ('93+'94+'95)	545	221[d]	68		40.55
1997 + ('93+'94+'95+'96)	545	247[d]	82		45.32
1998 + ('93+'94+'95+'96+'97)	545	272[d]	96		49.90

[a] Vines with external symptoms in the year indicated.
[b] Plants missed before 1993.
[c] In parentheses is given the number of symptomatic (*) and asymptomatic (**) vines that did not revegetate in the spring of the current year. These plants were uprooted and are marked with a **"V"** on the map in Figure 3.
[d] Vines which showed external symptoms for the first time in the year indicated plus all vines which had shown external symptoms in any previous year(s).

Table 4. Incidence of esca in a vineyard at Castelnuovo Berardenga (Siena), from 1995 to 1998.

Vineyard	Year	No. of standing plants	No. of symptomatic plants	September esca incidence (%)
	1995	512	12[a] (20)[b]	2.34
	1996	510	10[a] (2*)[c]	1.96
	1997	509	23[a] (1*)[c]	4.91
CBS1	1998	507	18[a] (2**)[c]	3.55
	1996 + ('95)	512	19[d]	3.71
	1997 + ('95+'96)	512	37[d]	7.22
	1998 + ('95+'96+'97)	512	52[d]	10.16
	1995	532	16[a] (28)[b]	3.00
	1996	532	25[a] (0)[c]	5.08
	1997	530	19[a] (2**)[c]	4.53
CBS2	1998	523	17[a] (2*+5**)[c]	3.25
	1996 + ('95)	532	34[d]	6.39
	1997 + ('95+'96)	532	49[d]	9.21
	1998 + ('95+'96+'97)	532	61[d]	11.46
	1995	1155	51[a] (173)[b]	5.11
	1996	1141	43[a] (6*+8**)[c]	5.61
	1997	1119	66[a] (21**)[c]	8.04
CBS3	1998	1088	47[a] (24**)[c]	4.31
	1996 + ('95)	1155	93[d]	8.05
	1997 + ('95+'96)	1155	159[d]	13.77
	1998 + ('95+'96+'97)	1155	218[d]	18.87

[a] Vines with external symptoms in the year indicated.
[b] Plants missed before 1995.
[c] In parentheses is given the number of symptomatic (*) and asymptomatic (**) vines that did not revegetate in the spring of the current year. These plants were uprooted the following winter.
[d] Vines which showed external symptoms for the first time in the year indicated plus all vines which had shown external symptoms in any previous year(s).

353 symptomatic plants and 47 apopletic strokes. In 1994 only 105 plants presented esca foliar symptoms and 22 were struck with apoplexy (a total of 69 apoplectic plants in the three years of the survey). However, only 8% of all these diseased plants showed foliar symptoms consistently in all 3 years in succession. If the black and white squares mapped in 1993 and 1994 and indicating symptomatic/asymptomatic vines are compared with the map for 1992 it is clear that most plants that were visibly diseased in 1992 did not have symptoms in 1993 nor in 1994. Similarly, the map showing diseased-looking plants in 1993 coincides very poorly with the map for 1994. This is an example of the year-to-year fluctuation or discontinuity in individual plants that bedevils esca symptom expression.

A consequence of this fluctuation is that it is impossible to trace the spread of the disease through a vineyard from year to year because even if we see a plant with external symptoms, there is no way of knowing whether this plant is newly infected, or has had the infection for a long time and is now expressing the symptoms again, or even for the first time.

The two maps of SCFI in Figure 2 show for 1993 and 1994, all the plants with external symptoms cumulated annually from 1992 to 1993 and to 1994. There is a gradual increase in the number of black squares, indicating plants with symtoms now mapped for the first time, and grey squares, indicating plants previously mapped as symptomatic and apopletic plants. The cumulated disease incidence of SCFI was 77.28% in 1993 and 82.25% in 1994. In that year only 107 plants (9.3%) of the 1156 with which the vineyard started in 1970 were still healthy looking, but it seems reasonable to believe that all, or almost all, the vines in the vineyard SCFI were really diseased. One of the main effects of esca disease is an eventual reduction in the life of the vineyard.

The nature of esca symptom expression over time raises some questions. When will a plant that is diseased but (still) asymptomatic start showing external symptoms? For how many years must observations be continued before the true disease incidence in a given vineyard can be certainly known as all asymptomatic plants are recognized? Conversely, if a plant is symptomatic, how many years earlier did the infection of that plant really occur? The answer to the first question is not simple, mainly because symptom expression in individual plants seems quite unpredictable. The maps in Figure 3 show the annual incidence of the disease in the vineyard at Gambassi Terme, a village on the border between the provinces of Florence and Siena, while those in Figure 4 show the cumulative incidence for the same vineyard calculated as above. This rose from 15.96% in 1993 to 49.9% in 1998. The annual disease incidence during this period however never exceeded 18.6%, in 1996. Table 5 shows how the 86 plants in this vineyard that were symptomatic in 1993 behaved in each of the six years following. Twenty-three of the plants showed symptoms only in 1993; they included two that were apoplectic in that year. In all subsequent years these plants vegetated and produced regularly. The remaining 63 plants with symptoms in 1993 showed a very different behavior: only two of these plants showed symptoms consistently for all 6 years of the observation period; 3 plants had symptoms in any 5 years out of 6, 12 in any 4 years, and 15 in any 3 years. There were therefore a few plants that showed symptoms every year for 5-6 consecutive years; but the great majority showed symptoms at much more irregular intervals.

Moreover, while some plants died in a year following one or more years during which they had been symptomatic; others died without any premonitory symptoms in the previous year or years. For example, plant No. 32 (Table 6) was asymptomatic for 5 consecutive years, then did not revegetate in the spring of 1998. Plant No. 35 was asymptomatic in 1993, apopletic the year thereafter, partly apopletic in 1995, asymptomatic in 1996 and again apopletic, this time in a definitive way, in 1997. In total, the 63 plants which died during the six-year test period showed 35 different sequences of symptom expression before they died. Those plants that first became symptomatic in a year after 1993 showed a similar variety in symptom expression, and all the variations that occurred in GTFI and SCFI were also found in the other vineyards surveyed (data not shown).

As regards the number of years during which a vineyard must be continuously monitored for the true rate of esca infection (including all 'hidden' or cryptic infections) to be ascertained, this too is not yet known. Currently a period of 3-5 years seems suffficient. A statistical analysis of all data from

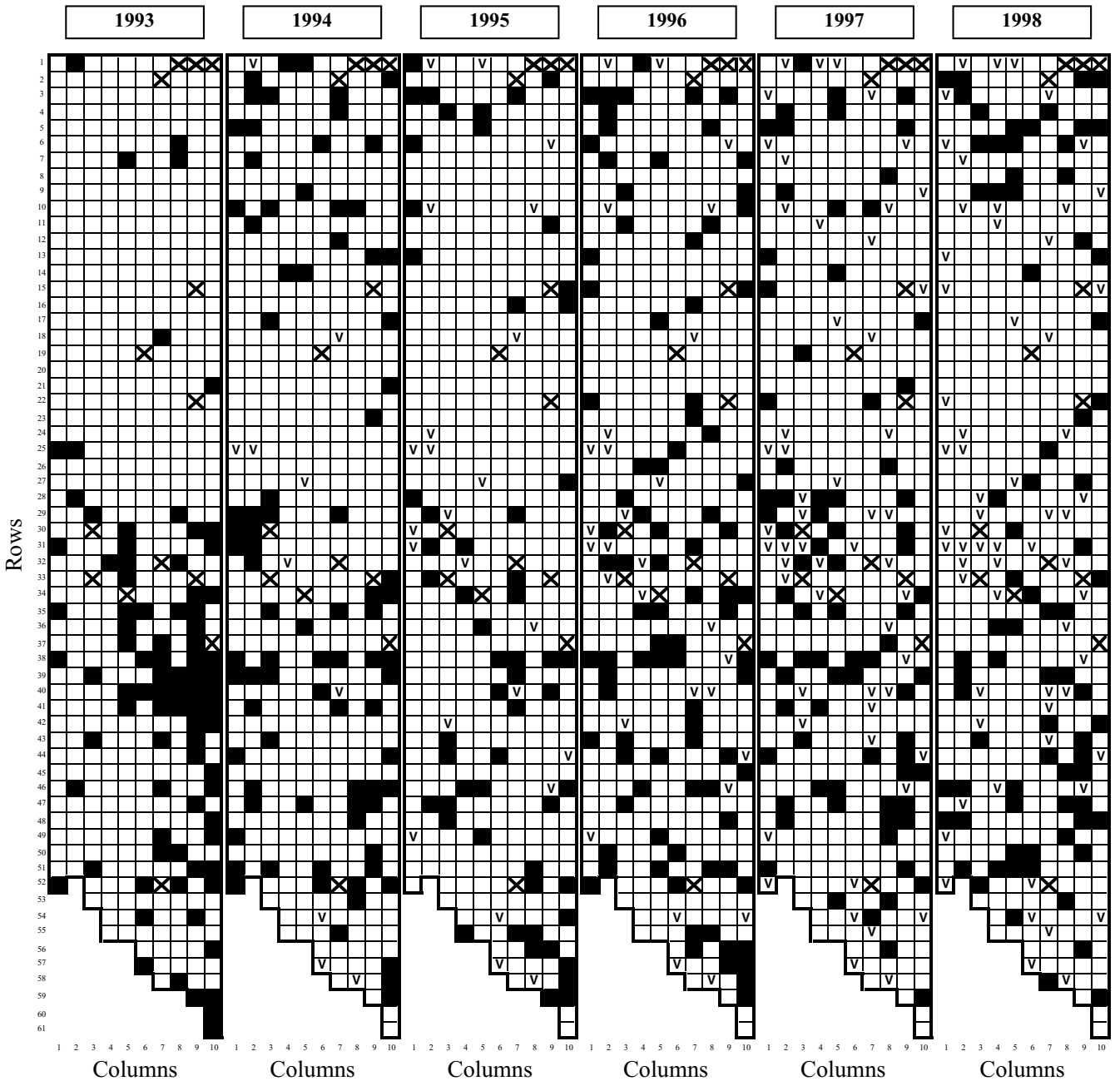

Fig. 3. Annual spatial pattern of esca-diseased plants in a vineyard at Gambassi Terme in the province of Florence. Black squares, symptomatic plants; open squares, asymptomatic plants; "**X**", plants died before start of survey (cause unknown); "**V**", plants died during survey period, with or without esca symptoms in the previous year.

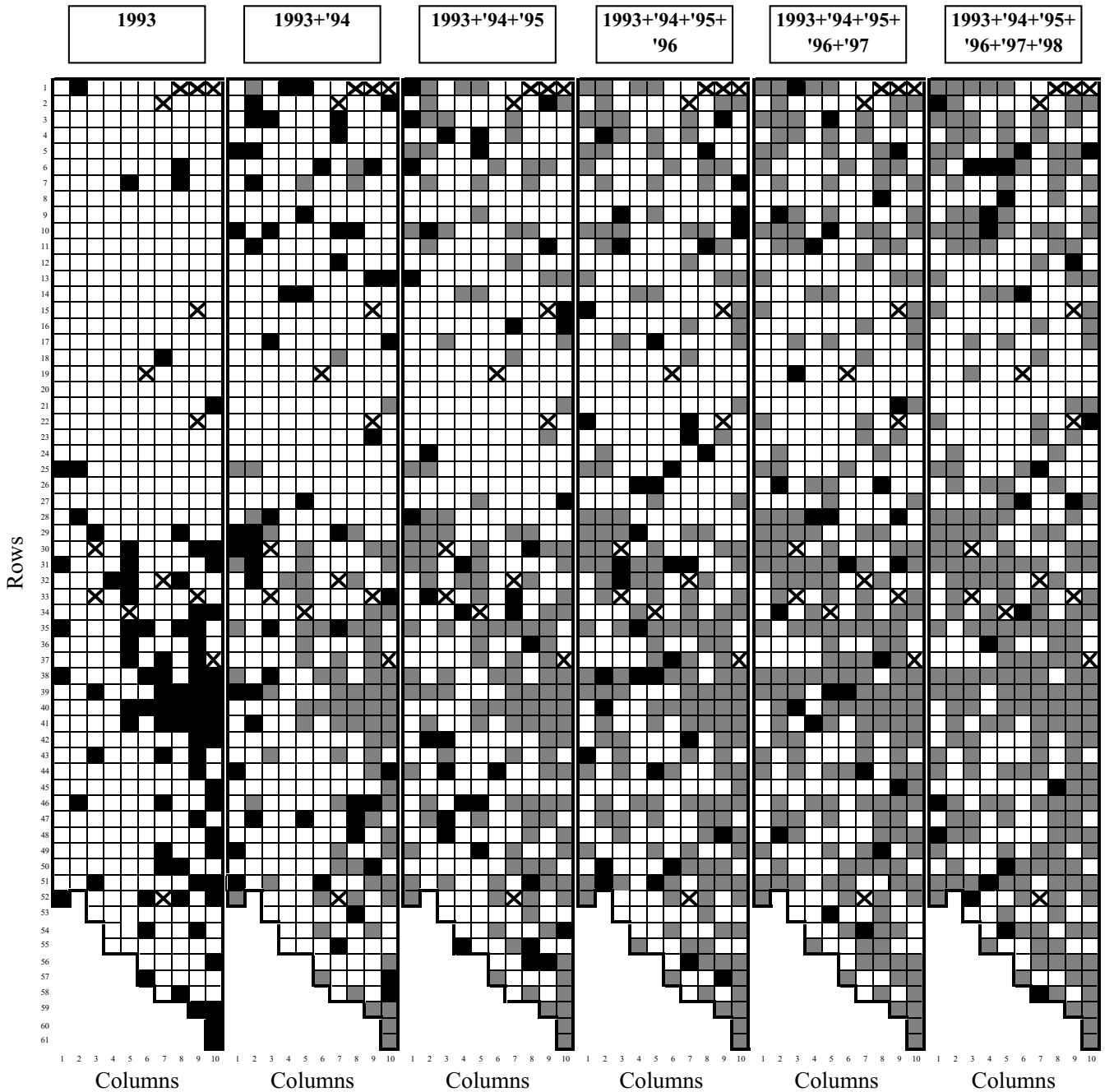

Fig. 4. Spatial pattern of esca-diseased plants in a vineyard at Gambassi Terme in the province of Florence cumulated. Black squares, symptomatic plants; open squares, asymptomatic plants; gray squares, symptomatic plants in previous years, or dead; "**X**", plants died before start of survey (cause unknown).

Table 5. External symptom expression from 1994 to 1998 in vines that had been symptomatic in the first year (1993) of the survey at Gambassi Terme (Florence).

Pattern number	Year						No. of plants[a]	Type of symptom detected in 1993[b]
	'93	'94	'95	'96	'97	'98		
1	+	+	+	+	+	+	2	●,×
2	+	+	+	-	+	+	1	×
3	+	+	+	+	D[c]		1	×
4	+	+	+	+	+	-	2	×[d]
5	+	-	-	+	+	+	3	×[d]
6	+	-	+	-	+	+	1	×
7	+	+	-	+	D		3	▲ (2 plants), ●
8	+	+	-	+	+	-	5	× (3 plants), ▲, ●
9	+	+	+	-	-	+	1	×
10	+	+	+	-	+	-	1	▲
11	+	+	+	D			1	×
12	+	+	+	+	-	-	1	×
13	+	-	-	-	+	+	1	×
14	+	-	-	+	-	+	1	×
15	+	-	-	+	D		2	×, ▲
16	+	-	-	+	+	-	2	×[d]
17	+	-	+	-	+	-	1	×
18	+	+	-	-	-	+	1	●
19	+	+	-	-	+	-	2	×[d]
20	+	+	D				2	●, ▲
21	+	+	+	-	-	-	3	×[d]
22	+	-	-	-	-	+	5	×[d]
23	+	-	-	-	+	-	2	×, ▲
24	+	-	-	D			2	×, ●
25	+	-	-	+	-	-	3	×, ●, ▲
26	+	-	+	-	-	-	1	×
27	+	D					9	● (8 plants), ▲
28	+	+	-	-	-	-	4	× (2 plants), ▲
29	+	-	-	-	-	-	23	● (2 plants), × (21 plants)

[a] Number of plants with the same sequence of annual disease symptoms.
[b] ● wilting of the whole plant (apoplexy); ×, only leaf chlorosis/necrosis; ▲, leaf chlorosis and wilting of some shoots and clusters.
[c] D, no renewal of growth in spring (dead plant).
[d] All the plants showed the same type of external symptoms.
+, presence of external symptoms; -, absence of external symptoms.

the present survey, and taking into account the weather data that seem most conducive to esca symptom expression (see below), is now under way, and it is hoped that this will provide an answer.

Weather parameters and expression of chronic esca

Which factors, internal or external to the plant, can cause such a discontinuity in symptom expression, which is surely unique in plant pathology, at least in this magnitude? It is known that in the northern hemisphere the external symptoms of esca appear mainly from June to August. Therefore, two seasonal factors that could, more than most, be expected to influence symptom expression are soil moisture and air temperature. Rives (1926) reported that dry summers were not favorable to esca and this was what emerged from our observations.

The annual disease incidence in GTFI, CBSI-1, 2 and 3 was fairly regular from one year to another; in SCFI, however, it was much higher in 1993, and lower in 1994, with 1992 in an intermediate position (Fig. 5): about 63% in 1993, and 19.62% in

Table 6. Sequence of external esca symptoms in a vineyard at Gambassi Terme (Florence) in the year(s) before the plant(s) died of apoplexy.

Sequence number	Year						No. of plants[a]
	'93	'94	'95	'96	'97	'98	
1	●[b]	D[c]					8
2	▲[d]	D					1
3	-[e]	D					1
4	●	●	D				1
5	▲	●	D				1
6	-	●	D				7
7	-	-	D				5
8	×[f]	-	-	D			1
9	●	-	-	D			1
10	×	▲	×	D			1
11	-	▲	●	D			1
12	-	-	●	D			3
13	▲	▲	-	●	D		2
14	●	●	-	●	D		1
15	×	×	×	▲	D		1
16	-	-	▲	●	D		1
17	-	-	●	▲	D		1
18	▲	-	-	▲	D		1
19	×	-	-	▲	D		1
20	-	×	-	●	D		4
21	-	●	-	●	D		1
22	-	-	-	-	D		4
23	-	-	-	●	D		3
24	-	●	●	▲	D		1
25	-	●	●	-	D		1
26	-	▲	▲	▲	D		1
27	-	-	×	▲	D		1
28	-	-	-	▲	●	D	1
29	-	-	-	●	●	D	1
30	-	-	●	●	●	D	1
31	-	-	●	-	●	D	1
32	-	-	-	-	-	D	1
33	-	-	-	-	●	D	1
34	-	-	▲	×	×	D	1
35	-	●	▲	-	●	D	1

[a] Number of plants with the same sequence of disease symptoms before mortality.
[b] ●, wilting of the whole plant (apoplexy).
[c] D, no renewal of growth in spring (dead plant).
[d] ▲, leaf chlorosis and wilting of some shoots and clusters.
[e] -, absence of external symptoms.
[f] ×, only leaf chlorosis/necrosis.

1994. This vineyard therefore appeared a promising place to study the influence of rainfall and temperature on annual disease incidence. Table 7 for SCFI shows the total monthly rainfall and number of days with rain in June, July and August, the monthly mean temperature for the same period, and the annual disease incidence, recorded in September. In 1992 there were more days with rain during the summer months than in 1993 or 1994. July 1992 was rainy, and so was June, and even August; cumulative precipitation was high; the temperature relatively low. In 1994, when disease incidence was lowest, there were only 9 days with rain in the 3 summer months; in August there was no rain at all, and the temperature averaged over these three months was the highest for the 3 years. In 1993, when disease incidence was highest, the weather parameters were more similar to 1992 than to 1994. Admittedly in the above analysis it was attempted to relate weather parameters recorded every month to the annual esca incidence, which is an insufficiently rigorous procedure, yet the data seem to suggest that the cool, wet summers of 1992 and 1993 were more favorable to esca symptom expression than the hot dry summer of 1994. At Gambassi Terme we were however able to measure disease incidence in June, July, August and September of 1996, 1997 and 1998 (Fig. 6). Taken one by one, the data in Figure 6 and those in Table 8 (for CBSI-1, 2 and 3) seem contradictory, at least in some cases, but on the whole they corroborate the view that a cool moist summer is conducive to esca. Finally, from the data in Figure 6 it emerged that symptoms on most plants appeared between June and July.

Weather parameters and apoplexy

It has always been thought that the sudden total or partial wilting of a vine (apoplexy) occurs particularly in summer, after heavy rain followed by dry, hot weather (Galet, 1977). We tried to verify this statement. Figure 7 (bottom) shows the monthly rainfall data from June to September 1996 at Gambassi Terme, and also the mean temperature and number of the apopletic strokes recorded by each survey date: 15 in July (3 by the 3d, 7 by the 16th and 5 by the 24th); 1 by the first of August; and 2 by the 9th of September. From the 23rd of June to the 18th of July there was no rain, but there were 10 apopletic

Table 7. Mean monthly temperature, monthly rainfall from June to August and incidence of esca in three vineyards at San Casciano Val di Pesa (Florence), 1992-1994.

Year and month	Rain periods	No. of days with rain	Total rainfall (mm)	Mean temperature (°C)	September esca incidence (%)
1992					46.43
June	3	15	94	18.6	
July	3	11	109	22.3	
August	2	2	41	24.1	
1993					63.37
June	5	9	90	21.2	
July	3	6	15	22.5	
August	4	5	67	24.5	
1994					19.62
June	2	6	59	19.7	
July	3	3	71	25.0	
August	0	0	0	24.9	

strokes out of a total of 18 for that year, i.e. 60% of all apopletic strokes occurred in a period when there was no rain but when the temperature was high. However, while the three apoplectic strokes on the survey date of 3 July could have occurred some or several days earlier, the 7 strokes by July 16 certainly occurred between the two survey dates of July 3 and July 16 (apoplexy has often a rapid onset and can be completed within a 24-h time-span) i.e. 11-22 days after a two-day rainy period that delivered a total of 18.5 mm. The average high and low and the mean temperatures from July 13 to 16 were 31.03, 16.1 and 23.6°C respectively. Five apoplectic strokes were detected on July 24, 5 days after a slight rainfall of only 4 l per square meter. The mean temperature from July 20-23 was 22.5°C while the mean maximum temperature for these days was 29.1°C, high, but not very high. On the

Table 8. Mean monthly temperature, monthly rainfall from June to August and incidence of esca in three vineyards at Castelnuovo Berardenga (Siena), 1995-1998.

Year and month	Rain periods	No. of days with rain	Total rainfall (mm)	Mean temperature (°C)	September esca incidence (%)
1995[a]					10.45
August	6	12	67.8	22.1	
1996					12.65
June	3	9	48	20.9	
July	6	7	33	22.6	
August	7	9	53	22.8	
1997					17.48
June	5	6	125	20.1	
July	4	6	20	22.7	
August	3	6	30	24.6	
1998					11.11
June	3	6	46	21.1	
July	1	1	3	24.5	
August	0	0	0	26.8	

[a] Only August data available.

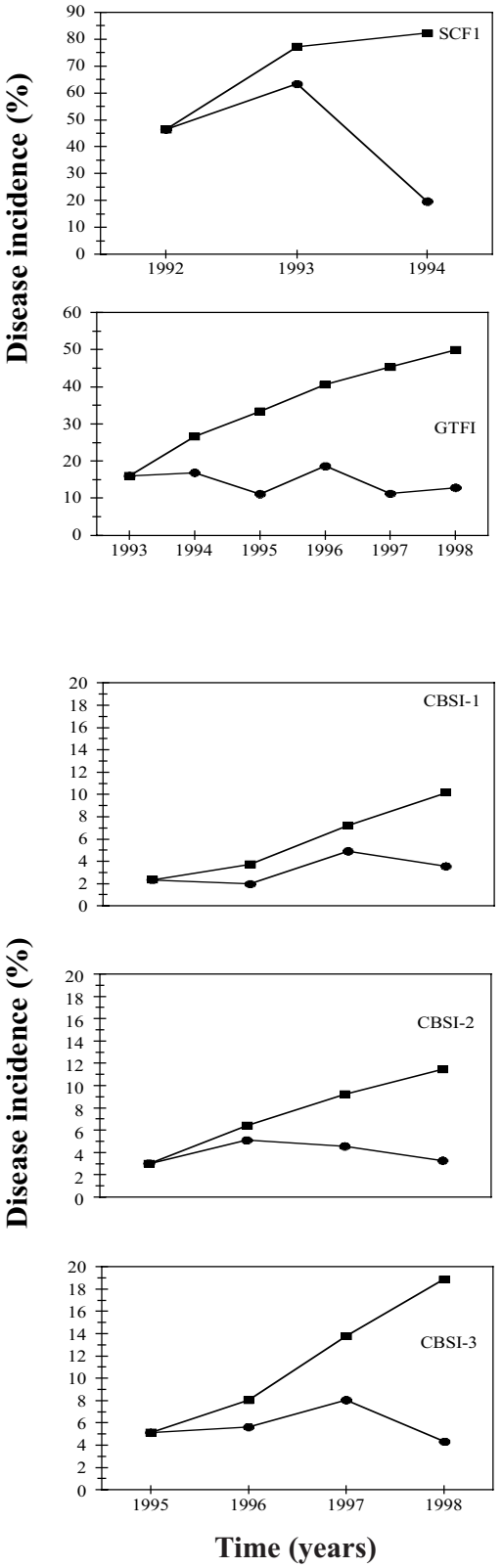

Fig. 5 (left column). Annual (●) disease incidence and cumulated incidence (■) in five vineyards at San Casciano Val di Pesa (SCFI), Gambassi Terme (GTFI) and Castelnuovo Berardenga (CBSI-1, 2 and 3).

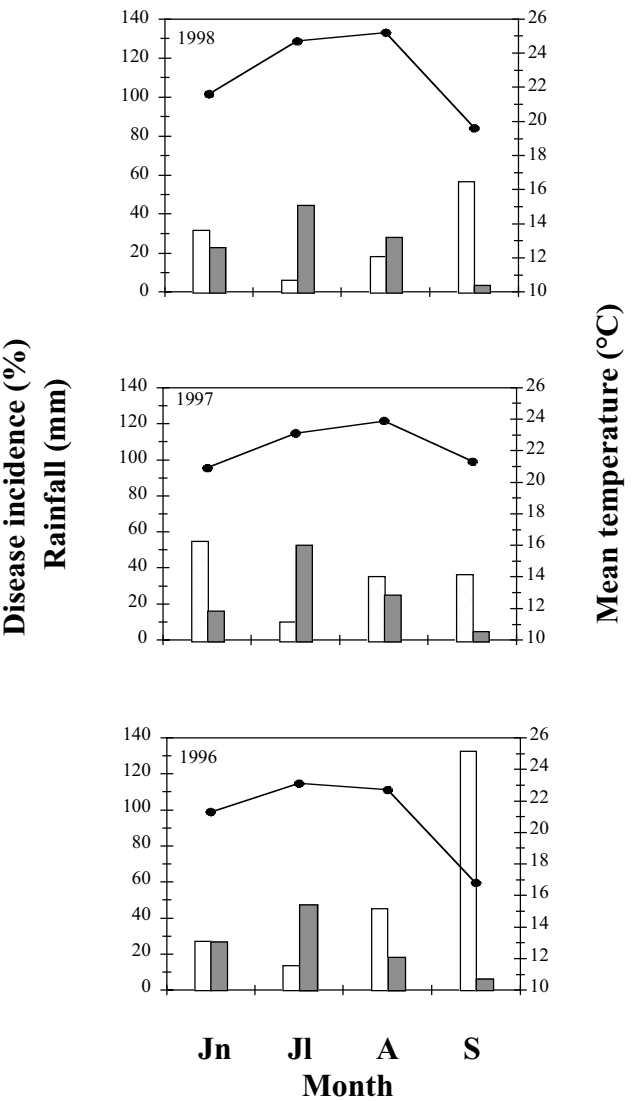

Fig. 6. Esca incidence (■), mean monthly temperature (●) and rainfall (□) in June (Jn), July (Jl), August (A) and September (S) 1996-1998 in a vineyard at Gambassi Terme (Florence).

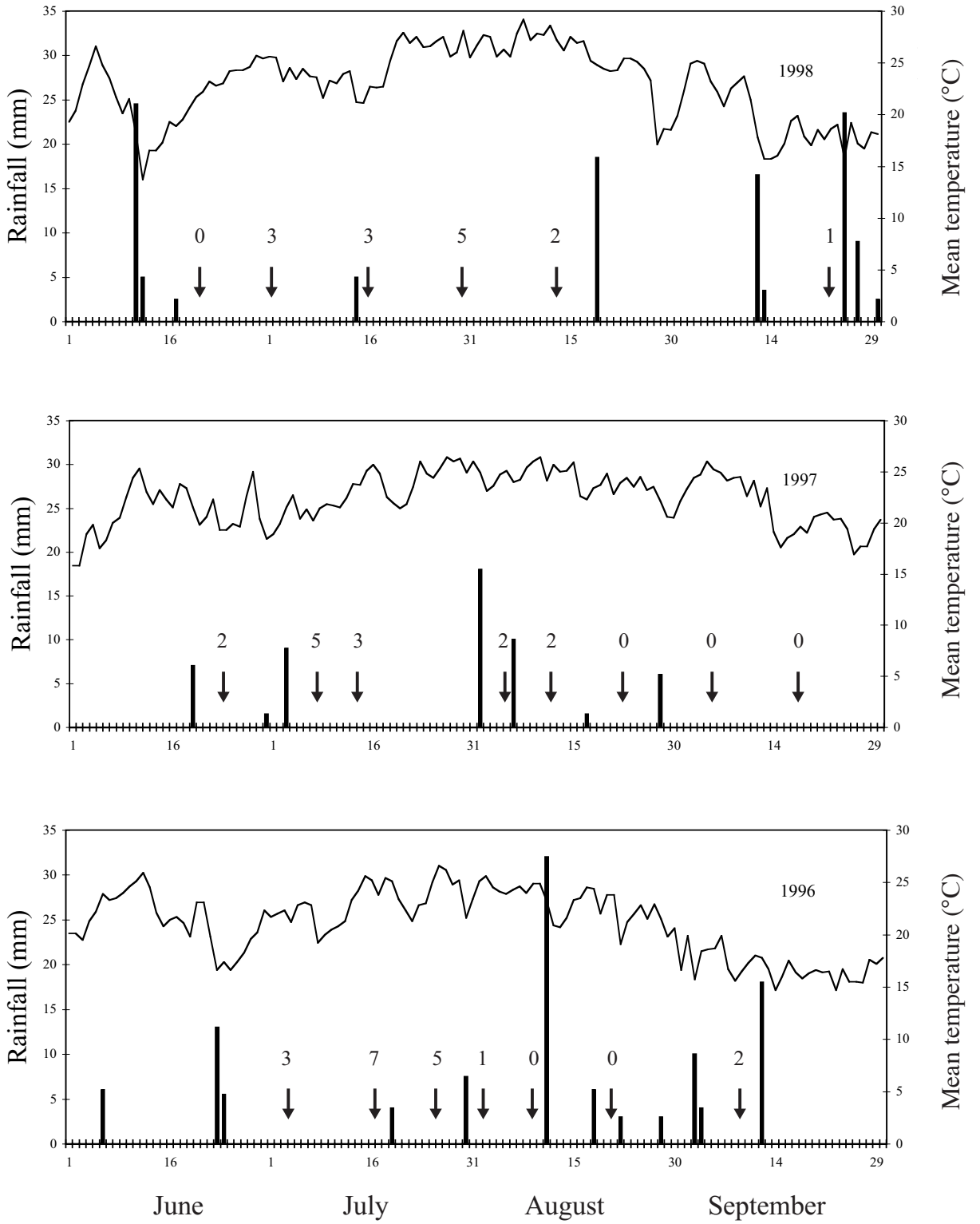

Fig. 7. Apopletic strokes (arrow), mean daily temperature (continuous line) and rainfall (bar) from June to September 1996-1998 in a vineyard at Gambassi Terme (Florence).

other hand, after the rainfall of July 19, the mean daily temperature decreased, to increase again from the 24th onward. In August an apoplectic stroke was observed 2 days after a rainfall of 7.5 mm and then there were several days with rain but without any strokes. The temperature was quite variable, but low for August. Finally, 2 apopletic strokes were detected at the September survey date which could have occurred in August. From these data it could be concluded that rain is not an important factor for apoplexy, and that temperature is more important. In 1997 14 apopletic strokes were counted: 2 in June, 4 days after a rainfall of 7.5 mm; 8 in July, after a rain of 8.5 mm, and 4 in August, not long after two rainy days (Fig. 7, middle). In that year there was a closer association between rain, high temperature and apoplexy. In 1998 the situation was not very different from that in 1996 (Fig. 7, top). A possible conclusion is that apoplexy mainly occurs early in the season under conditions of water stress and high temperature.

Other factors that influence symptom expression

Other factors that may influence expression of external esca symptoms include vine age, cultural practices, soil type and the cultivar, to mention only the most obvious. Here we shall consider the cultivar and the slope of the vineyard.

Figure 8 shows the number of infected vines per column in GTFI, SCFI, CBSI-1, 2 and 3.

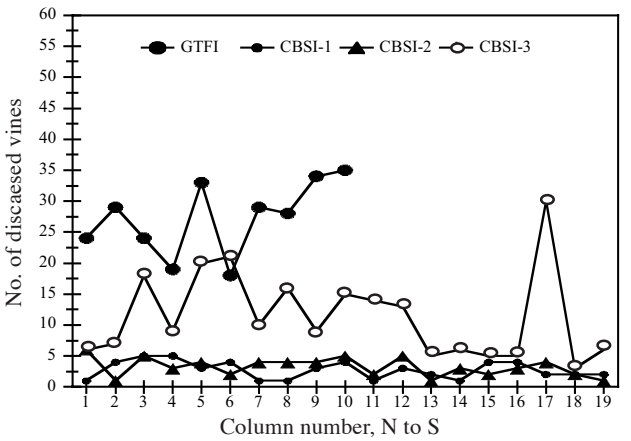

Fig. 8. Number of diseased vines per column in four vineyards at Gambassi Terme (GTFI) and Castelnuovo Berardenga (CBSI-1, 2 and 3).

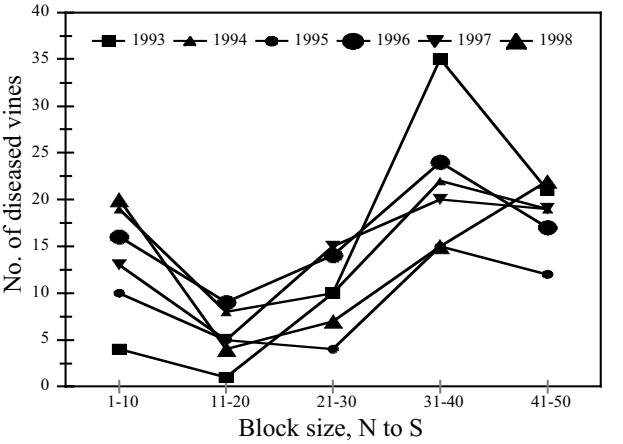

Fig. 9. Number of diseased vines per block of ten rows (10 plants per row) in a vineyard at Gambassi Terme from 1993 to 1998.

While in CBSI-1 and 2 this number did not vary much, in CBSI-3 and GTFI it varied from column to column. CBSI-3 presented an interesting case. This vineyard consisted of 19 columns of about 50 vines per column, each column being planted with a different cultivar except columns 3 and 11, and 13 and 14, which had the same cultivar. The data suggested that some cultivars could be more susceptible to esca than others. It seemed more difficult to account for the findings in GTFI. This vineyard was divided into blocks of ten rows and the number of diseased vines was

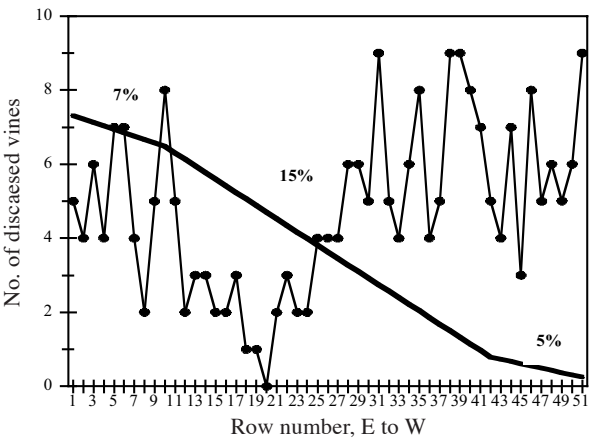

Fig. 10. Number of diseased vines in each row of a vineyard at Gambassi Terme. The slope (%) of the vineyard is also shown.

counted separately for each block (Fig. 9). A certain disease gradient was observed in all years of survey (1993-1998) with a lower disease incidence in the second block and a gradual increase towards the edge of the vineyard. Figure 10 shows the number of diseased vines in each row and also the slope of the field. A lower disease incidence was found where the slope was steeper, and a higher incidence where the slope was more level. Similar variations relating to the slope were also observed at San Casciano Val di Pesa and Castelnuovo Berardenga.

Conclusions

The findings of the survey confirmed and supplemented previous knowledge on discontinuity in the external symptoms of esca (Hewitt, 1957; Mugnai *et al*., 1996, 1999). In all the vineyards studied, disease incidence varied from year to year, up or down, perhaps in relation to the amount of summer rainfall and/or the air temperature. It is however clear, and the data corroborate, that in years favorable to esca symptom expression, the annual recorded incidence will be closer to the real (cumulative) incidence in a vineyard.

At San Casciano Val di Pesa the differential between the incidence recorded each year and the total (cumulative) incidence based on data for three years, was 44% in 1992, 23% in 1993 and 76% in 1994. From this it is clear that in 1993, unlike in 1994, the conditions that obtained, though mostly unknown, were more favourable to the emergence of the external symptoms of esca. If disease incidence had been recorded only in 1993 and 1994, then in 1993 the recorded incidence would have corresponded fairly well to the real incidence, but in 1994 the approximation between recorded and real incidence would have been much rougher.

In GTFI and CBSI-1, 2 and 3 the situation was slightly different. Here the differential between annual recorded and cumulative disease incidence never went below 50%. In none of these years, therefore, were conditions clearly favorable for abundant symptom expression. To this it should be added that, during this same period, different differentials were found between annual incidence and cumulative incidence in CBSI-1, 2 and 3, even though these vineyards are contiguous to each other and would be expected to present very nearly the same esca incidence at all times. From this it is evident that the occurrence of external esca symptoms must be influenced by some other factors besides the possible effect of rainfall and temperature. Such other factors could be for instance the slope of the terrain, or the cultivar.

Since the incidence of esca can only be determined by visual inspection, it is impossible to tell whether at SCFI or indeed at GTFI and CBSI-1, 2 and 3, all diseased plants showed external symptoms within the survey period, and to what extent plants newly infected added to the disease incidence each year.

To calculate the true total esca incidence reliably, without missing any diseased plants, it is therefore necessary to extend the survey period over a sufficiently long time, not less than 3-5 years.

The data reveal that it is very difficult to predict the occurrence of external esca symptoms in a given year. Infected plants behave in a way that seems completely erratic. Plants that are strongly symptomatic one year may grow and produce almost normally the next, and plants that outwardly seem normal in one year (although in fact the wood of the trunk is always more or less rotted) will not vegetate at all the following year. Between these two extremes there lies a whole gamut of intermediate cases (Tables 3 and 4). It would almost seem that the relation between rot of the trunk and the external symptoms (leaf chlorosis/necrosis) is much more complicated than previously thought or even that these external symptoms have a different origin altogether. In this connection new hypotheses have recently been advanced on the nature and origin of esca (Graniti *et al*., 1999).

Lastly, a somewhat clearer picture of the occurrence of apoplectic strokes in the vineyard has emerged from the present study. It does seem that the acute form of esca appears in summer in conditions of water stress and hot weather, and not, or not always, after heavy rains followed by hot weather. On the other hand, a cool rainy summer seem to be favorable to the chronic form of esca.

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