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Some observations on the relationship of manifest and hidden esca to rainfall

Guido Marchi[1], Francesca Peduto[1], Laura Mugnai[1], Stefano Di Marco[2], Francesco Calzarano[3] and Giuseppe Surico[1]

[1]Dipartimento di Biotecnologie Agrarie, Sezione di Patologia vegetale, Università, P.le delle Cascine 28, 50144 Firenze, Italy
[2] Istituto di Biometeorologia, Sezione di Bologna, CNR, Via Gobetti 101, 40129 Bologna, Italy
[3] Facoltà di Agraria, Università di Teramo, Via Spagna 1, 64023 Mosciano S.A., Teramo, Italy

Summary. This paper reports observations on the relationship between the yearly incidence of manifest esca (i.e. diseased plants which show foliar symptoms), hidden esca (that which remains asymptomatic throughout a growing season) and rainfall. Data from three vineyards (two in Tuscany and one in Emilia-Romagna, Italy) showed that rainfall in May–July or only in July was inversely related with hidden esca. For two vineyards, TB in Emilia-Romagna and CAR-3 in Tuscany, the spatial pattern of diseased vines in the first year of appearance of the foliar esca symptoms was also determined. The maps of the vines in these vineyards indicated that diseased plants mostly occurred alone. This suggests that the disease had its origin in infected rooted cuttings or was triggered by inoculum aerially dispersed from distant sources and/or occurring, at least in hypothesis, in the soil.

Key words: grapevine, symptom expression, rainfall, disease progress, spatial distribution.

Introduction

It is well known that one of the peculiar characteristics of esca of grapevine is that the visible (leaf) symptoms of the disease are intermittent: they do not appear on diseased vines rigorously every growing season, but may fail to appear in a certain year, or even for some years in succession, during which time the diseased vines are asymptomatic, and to all intents and purposes indistinguishable from healthy vines (Hewitt, 1957; Baldacci *et al*., 1963; Mugnai *et al*., 1996; Surico *et al*., 2000a; Calzarano *et al*., 2001). Epidemiological studies carried out during the summer months in the 1990s in some Tuscan vineyards which at the time were 13–22 years old have led to a better understanding of this intermittent nature of visual symptom expression of the disease (Surico *et al.,* 2000a). Inspections carried out for 6 consecutive growing seasons (1993–1998) in one of these vineyards in the Province of Florence, for example, found that 86 of the vines were symptomatic in the first year; of these, some 27% did not show symptoms again in any of the following 5 years, and only 2% were symptomatic every year without intermission during the entire 6-year inspection period. This yearly discontinuity of esca-diseased grapevines, which may be unique in the whole field of plant pathology, makes it almost impossible to determine the true incidence of esca in a given vine-

Corresponding author: G. Marchi
Fax: +30 055 3288273
E-mail: guido.marchi@unifi.it

yard at any time. In the 6-year survey mentioned above, for example, the annual incidence of symptomatic vines was about 16% in 1993 and again in 1994 (though by no means always on the same vines), 11% in 1995, about 19% in 1996, 11% again in 1997 and 13% in 1998. The cumulative incidence on the other hand, comprising all vines that had displayed symptoms in at least one of the survey years, and thought to approximate to the real incidence of esca, amounted to 49.9% in 1998.

In this context vines are said to exhibit 'manifest esca' in any year when they show external symptoms of the disease; in years when these diseased vines remain asymptomatic on the other hand they are said to have 'hidden esca'. As has been said, these two 'types' of esca vary relative to each other from year to year depending at least in part on the rainfall pattern in certain summer months, as we try to show in this paper, but the disease as a whole (manifest + hidden = cumulative esca) gradually becomes more common over time.

When during the 6-year survey mentioned above inspections were carried out more than once during individual growing seasons, it was further found that on average every year about 83 per cent of the total number of apoplectic strokes (acute esca) and 72% of the cases of chronic esca that would arise in that year were already visible in or before the end of July, that 99 and 96% of apoplexy and manifest esca respectively occurred by the end of August, and that only 1 and 4% respectively of these types of esca made their appearance belatedly in September. Similar patterns have consistently been found in other vineyards in central Tuscany. From all these findings it appears that incidence estimates based on visual symptoms, especially if they are calculated from only one year of inspection, do not indicate the true scale of esca, and that the factor or factors predisposing vines to manifest esca in a given year are already operative in the first half of summer, and vary in their effectiveness from year to year. As regards this last point, it was found in a previous study (Surico *et al.,* 2000a) that cooler and rainier summers favoured the development of chronic esca symptoms, while acute esca (apoplexy) was more common in mid-summer under conditions of water stress.

It has been found that all three fungi currently implicated in esca (*Phaeomoniella chlamydospora*, *Phaeoacremonium aleophilum* and *Fomitiporia mediterranea*) harbour multiple factors of pathogenicity and virulence that are potentially involved in the disease process (Mugnai *et al.,* 1997a; Mugnai *et al.,* 1997b; Evidente *et al.,* 2000; Sparapano *et al.,* 2000; Tabacchi *et al.,* 2000; Marchi *et al.,* 2001), and that of these fungi at least one, *P. chlamydospora,* triggers some defence reactions in its grapevine-host (Amalfitano *et al.,* 2000; Del Rio *et al.,* 2001), but it still remains to be seen whether, and how, these factors have a role in the virulence of esca fungi, and how the interaction between host and pathogen is affected by the environment.

In what follows the results of an explorative study are presented on the patterns of visual esca symptoms in four vineyards monitored over a period of time varying from 6 to 14 years.

Materials and methods

The spread of esca was determined annually in the first 10 days of September in four vineyards located l. in the province of Siena (CBSI4; survey from 1995); 2. in the province of Florence (ISO-A; survey from 2000); 3. in the province of Prato (CAL-3; survey in 2005); and 4. in the province of Ravenna (TB; survey from 1991) (Table 1; Fig. 1). At each inspection date all vines were examined for external symptoms of esca, distinguishing between chronic esca (leaf symptoms) and acute esca (apoplexy). Each year a two-dimensional map was drawn of each test plot showing each vine and its health status in that year. In addition, after the first year all vines which, though asymptomatic in the year of mapping, had shown visual esca symptoms in at least one of the preceding years, were also added to these annual maps, thus creating an in-depth picture that would show the cumulative incidence of esca.

The proportion of esca-diseased vines that did not show the visual symptoms of esca (hidden esca) in a vineyard in a given year was expressed as the ratio of the number of asymptomatic diseased vines (known from inspections in previous years) over the number of symptomatic vines plus the number of asymptomatic diseased vines and multiplying by 100.

Rainfall and temperature data during the solar year were recorded daily for each vineyard. The data relating to the vineyards ISO-A and TB were

Table 1. Characteristics of the four vineyards surveyed for esca in the present study.

Characteristic	Vineyard			
	CBSI4	ISO-A	TB	CAL-3
Year planted	1987	1987	1991	2001
Cultivar	C. Sauvignon	C. Sauvignon	Albana	C. Sauvignon
First year of survey	1995	2000	1991	2005
No. of years surveyed	10	5	13	1
No. of plants surveyed	597	1299	1499	1624
First year of appearance of foliar symptoms	1995 (?)[a]	2000 (?)[a]	1999	2005(?)[a]

[a] Vines with symptomatic esca may have occurred before the survey was initiated.

recorded by weather recording equipment located in the vineyards themselves, while the data for vineyard CBSI4 were recorded for the period 1997–2004 by a weather-station located about 7 km away in a straight line. The degree of relationship between the proportion of diseased vines expressing visible symptoms and the amount of rainfall in the period preceding an inspection date, was calculated by simple linear regression analysis following the method of least squares.

Results

In vineyards CBSI4, ISO-A and CAL-3 the epidemiological survey was initiated when the vineyards were 8, 12 and 4 years old respectively, and

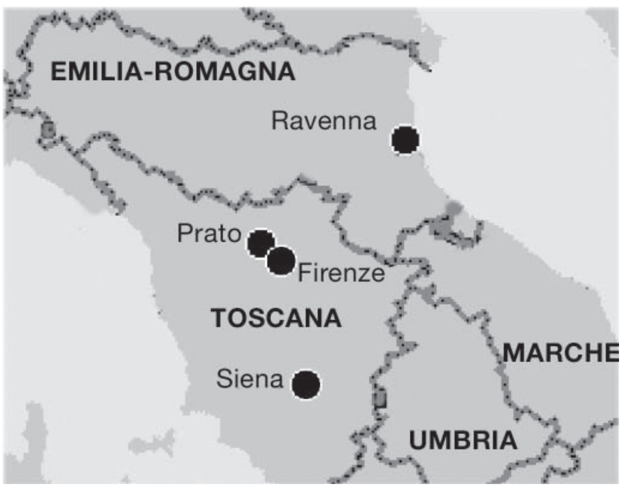

Fig. 1. Geographical location of the four vineyards examined in the present study.

visual symptoms of esca were detected from the first year of the survey. The possibility can therefore not be excluded that vines in these vineyards already had esca symptoms before the survey began. In vineyard TB, on the other hand, which was established in 1991 and inspected from the start, the first visual symptoms of esca did not appear until 1999, by which time the vineyard was 8 years old. The map of CAL-3 in Figure 6 show for 2005 all the plants with external symptoms (1.7%). In vineyards CBSI4, ISO-A and TB the annual esca incidence during the inspection period fluctuated widely from year to year (Fig. 2) with peaks of 25.5% in CBSI4 in 2002; 15.7% in TB in 2004; and 31.5% in ISO-A in 2002, and lows of 1.5% in CBSI4 in 1995, 1.6% in TB in 2003 and 15% in ISO-A in 2001. The cumulative incidence of esca on the other hand increased steadily in the three vineyards during these years (Fig. 2) so that at the end of the inspection period it was 45% for CBSI4, 19.5% for TB and 51.2% for ISO-A. In these vineyards the number of known diseased vines that did not express visual symptoms (vines with hidden esca) also varied from year to year (Fig. 3 and 4). Nevertheless, at least during the four years 2001–2004 for which data on all vineyards are available, the pattern of hidden esca incidence was similar in these vineyards: starting from a base-line in 2001, it diminished in 2002, increased again in 2003, to diminish again in 2004. Linear regression analysis detected that between 48 and 92% of the variation in the incidence of hidden esca from year to year and between vineyards was accounted for by the amount of rainfall in the May–July period, or indeed in the month of July alone, in each vineyard. Nevertheless the relation between esca incidence and rainfall attained statistical significance in only 2 cases: in vineyard CBSI4 in July (F=11.85, $P<0.02$), and in vineyard TB in May–July (F=34.96, $P<0.01$). In vineyard ISO-A the relation between esca and rainfall was not statistically significant even though the calculated coefficient of determination (R^2) indicated that approximately 73% of variation in the incidence of hidden esca from year to year was accounted for by variation in the rainfall in May–July, and 81% by variation in July.

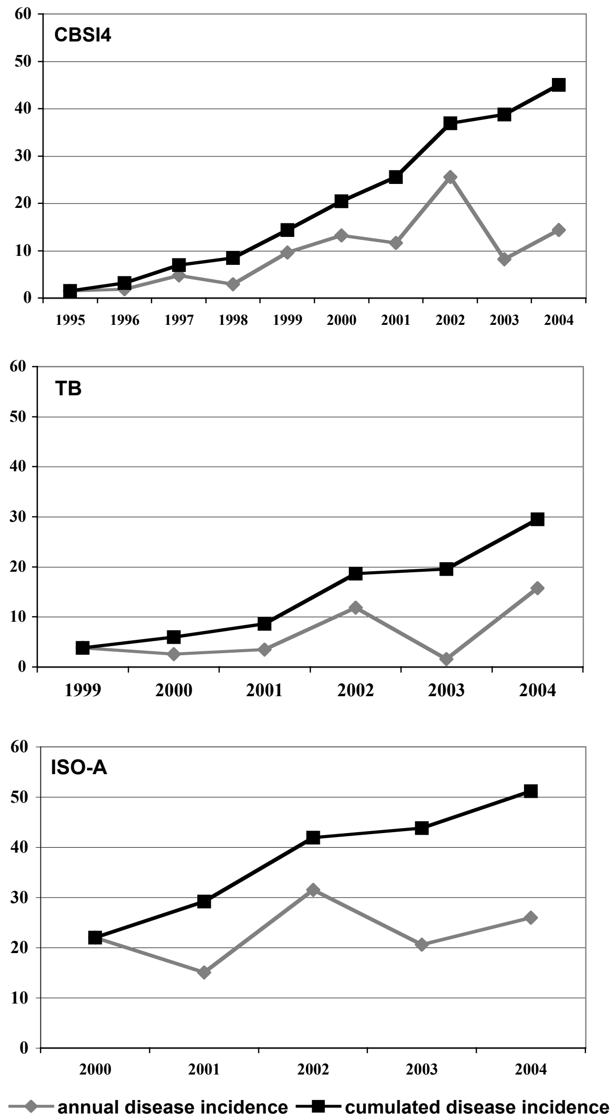

Fig. 2. Annual incidence of manifest esca (◆) and cumulated esca (■) in three vineyards at Siena (CBSI4), Ravenna (TB) and Florence (ISO-A).

The distribution of diseased vines in the vineyard found in the survey confirmed earlier findings (Surico *et al.,* 2000b). Initially, when the (visual) esca incidence was still low, symptomatic

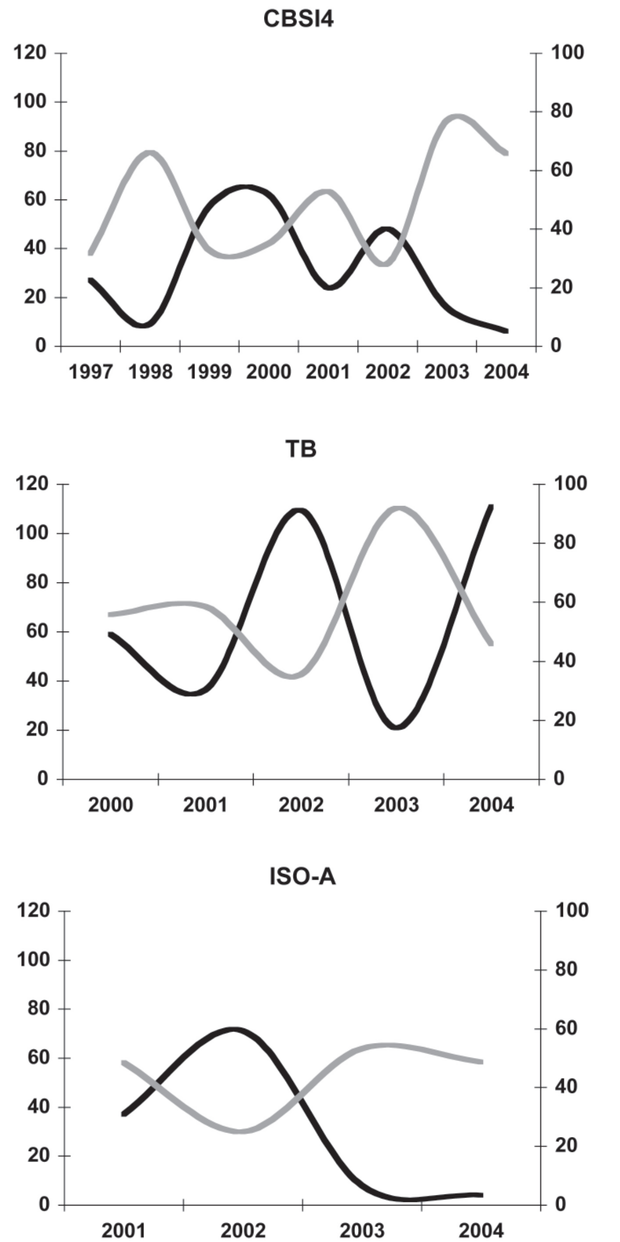

Fig. 3. Relation between rainfall in July and the percentage of standing vines with hidden (i.e. asymptomatic) esca in three vineyards at Siena (CBSI4), Ravenna (TB) and Florence (ISO-A).

vines occurred alone or in groups that were usually of small size (Fig. 5, 6 and 7). As the incidence increased (Fig. 7), the groups of diseased vines began to form into larger groups, and these in turn grew larger still and became confluent (Fig. 8)

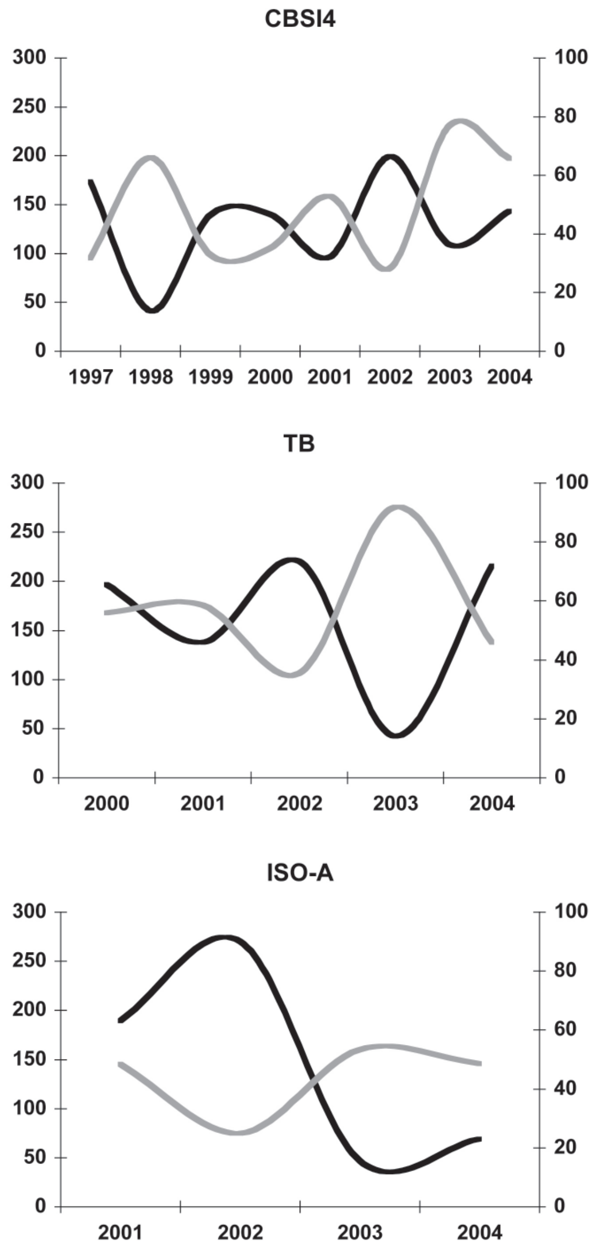

Fig. 4. Relation between rainfall in May, June and July and the percentage of standing vines with hidden (i.e. asymptomatic) esca in three vineyards at Siena (CBSI4), Ravenna (TB) and Florence (ISO-A).

Discussion

To explain the erratic nature of the foliar symptoms of esca, factors extraneous to the plant-pathogen complex itself have been postulated (Mugnai *et al.,* 1999). The effectiveness of these factors was assumed to vary over the course of the growing season, and to affect significantly the extent to which diseased vines expressed visual symptoms. Earlier investigations (Surico *et al*., 2000a) showed that on average the first visual symptoms appeared in June (or even at the end of May in Sicily and Sardinia, Burruano and Serra, personal communication) and that more than 70% of all vines that were symptomatic in September had already expressed their visual symptoms by the end of July. It therefore seems reasonable to assume that it is in the period from the onset of vegetative growth to the end of July that the particular conditions that prompt symptom expression in diseased vines arise. Regression analysis taking the operative factor to be the amount of rainfall in May–July, or indeed only in July, detected that, at least in vineyards TB and CBSI4, rainfall was inversely related with hidden esca.

It therefore seems that in vineyards CBSI4, TB and ISO-A relatively cool growing seasons like that in 2002 favoured the expression of visual symptoms in some way, thereby reducing the amount of hidden esca, while drier seasons such as that in 2003 increased the amount of hidden esca, with a lower proportion of vines showing visual symptoms. That water availability may have a role in symptom expression received further confirmation from the fact that in vineyards that gradually slope down to a level area, which are very common in Tuscany, esca incidence is almost always greater in the level areas (Surico *et al.,* 2000a), where presumably more water accumulates and may stagnate.

At present the precise role of rainfall in esca symptom expression has not yet been established. Perhaps a greater and more constant flow of water towards the leaves favours the accumulation of higher levels of phytotoxic substances in those leaves, leading to the appearance of symptoms as soon as a critical threshold is reached. Experiments now under way are designed to explore this aspect of the plant-pathogen interaction.

As regards the spatial pattern of diseased vines in the vineyards, vineyard CAL-3, which was only 4 years old, clearly showed that diseased vines grew

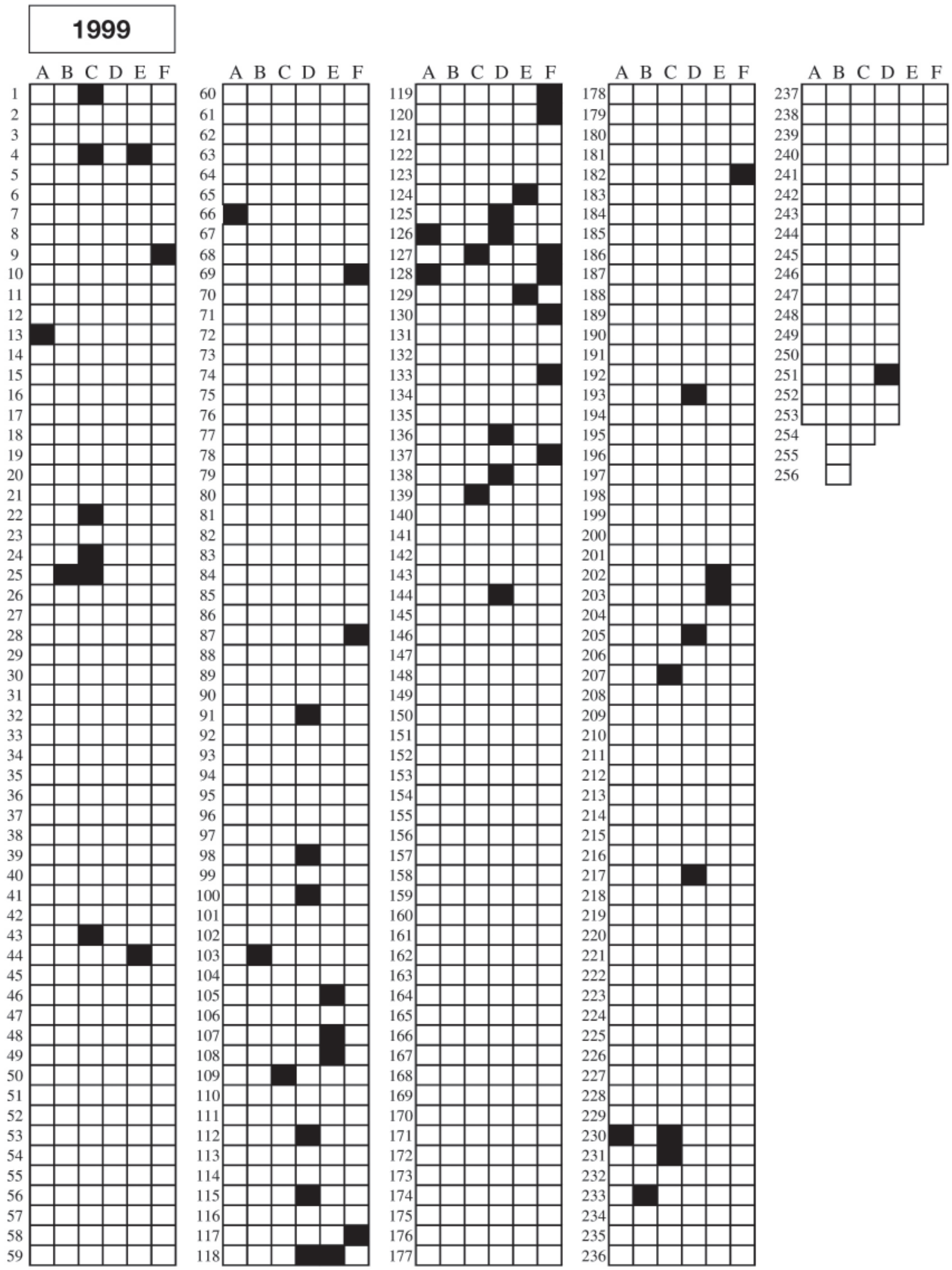

Fig. 5. Spatial pattern of esca-diseased plants in vineyard TB in the province of Ravenna in 1999 (first year of appearance of foliar esca symptoms in the vineyard). Black squares, symptomatic plants; open squares, asymptomatic plants.

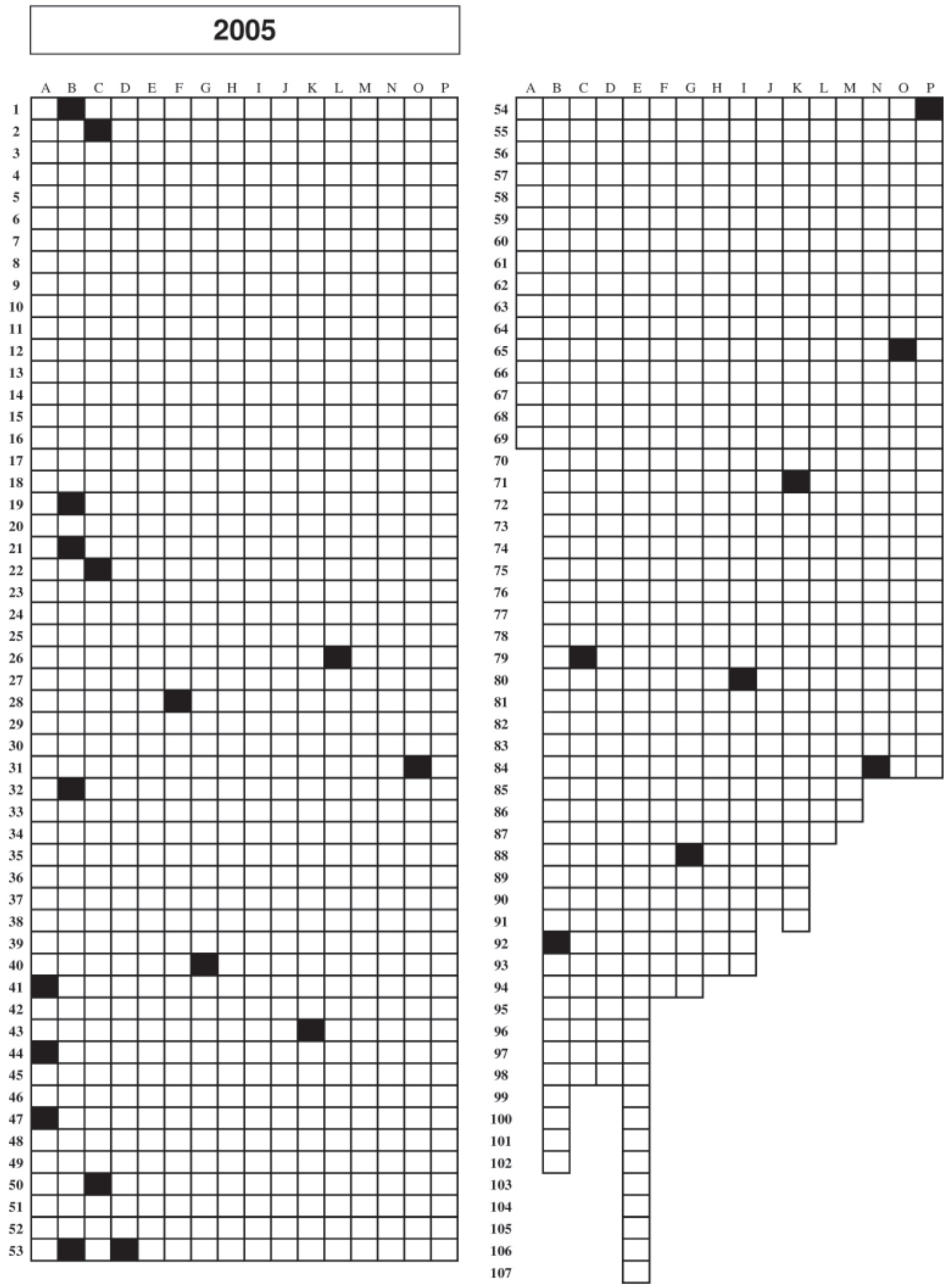

Fig. 6. Spatial pattern of esca-diseased plants in vineyard CAL-3 in the province of Prato in 2005. Black squares, symptomatic plants; open squares, asymptomatic plants.

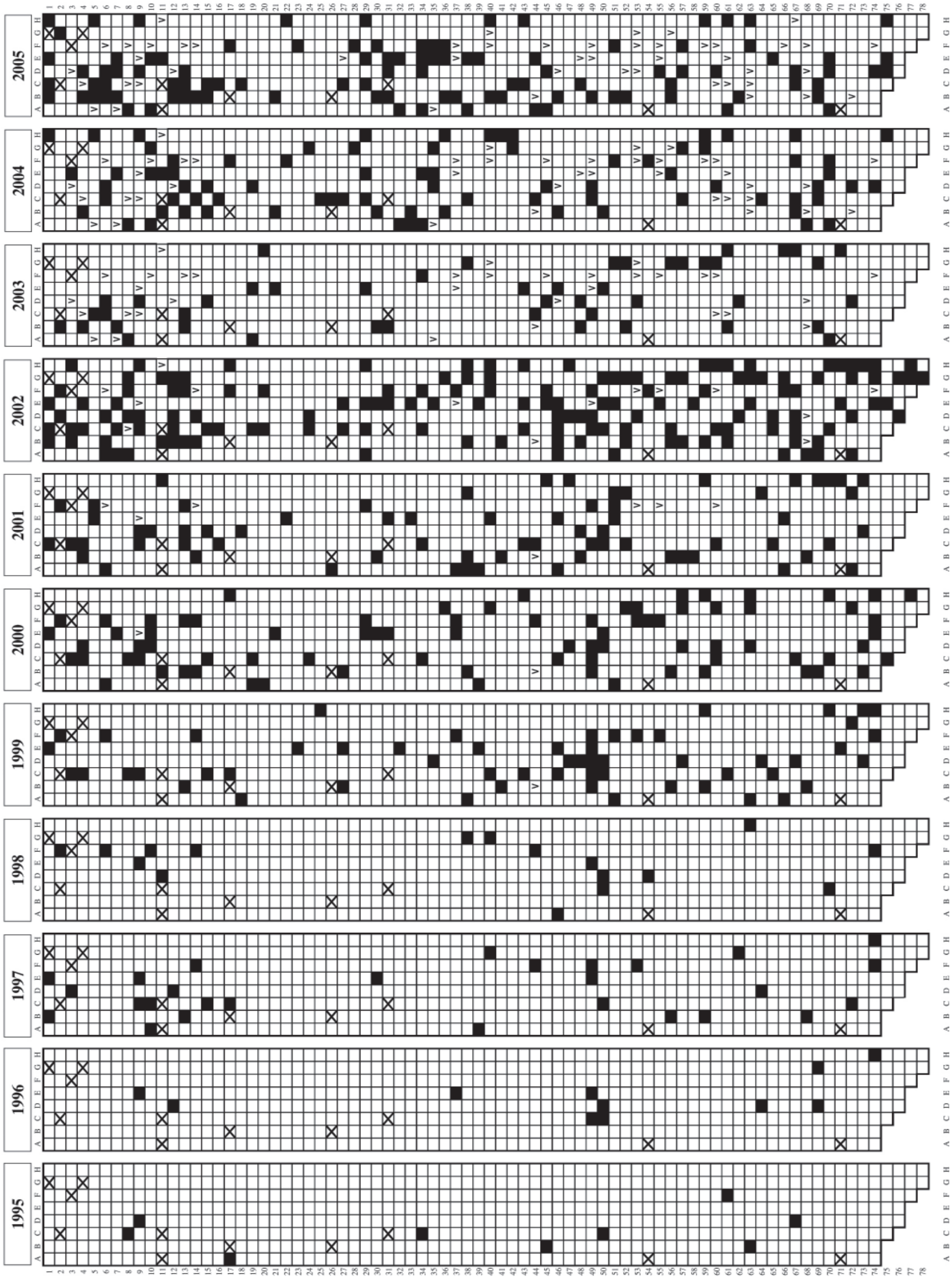

Fig. 7. Annual spatial pattern of esca-diseased plants in vineyard CBSI4 in the province of Siena. Black squares, symptomatic plants; open squares, asymptomatic plants; '×', plants died before start of survey (cause unknown); '>', plants died during survey period, with or without esca symptoms in previous years.

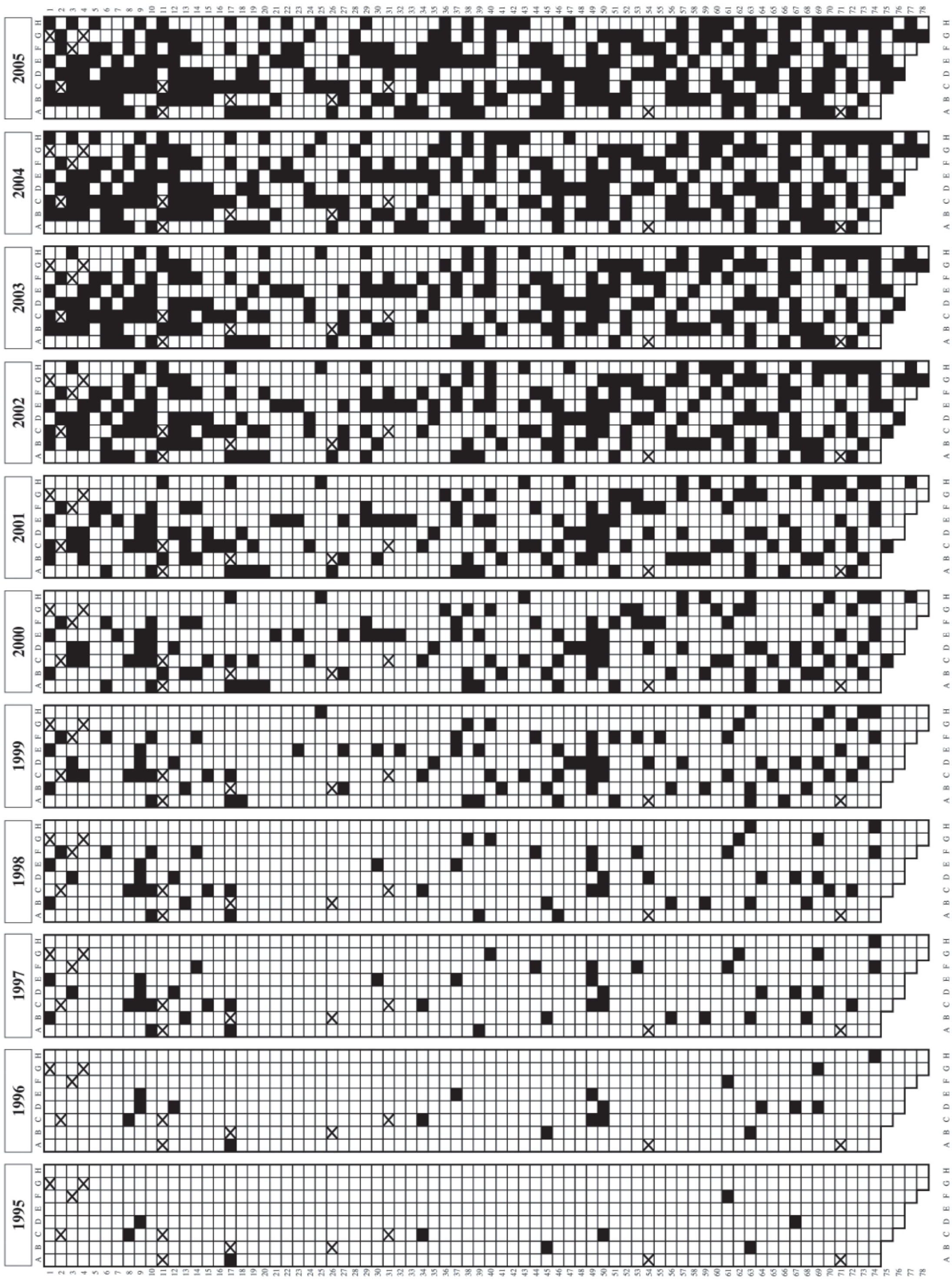

Fig. 8. Spatial pattern of esca-diseased plants in vineyard CBSI4 in the province of Siena. Black squares, symptomatic plants in current year or in one or more previous years; open squares, asymptomatic plants; '×', plants died before start of survey (cause unknown).

isolated from each other, but that the distribution of such isolated vines was nearly uniform. This suggests that the disease possibly has its origin in infected rooted cuttings or inoculum that may have come from any direction whatever.

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