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Effects of apple cultivar susceptibility to *Venturia inaequalis* on scab epidemics in apple orchards

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Abstract

The effects of cultivar susceptibility on the development of scab caused by *Venturia inaequalis* were observed in two experimental orchards where no fungicide protection was used against scab over a 5-year period. The weather during a 4-year period was conducive to apple scab development, and the results obtained demonstrate the advantages of using low-susceptibility cultivars to limit the development of apple scab epidemics on leaves as well as on fruits. Whereas 95.2–100% of the fruits of susceptible cultivars had apple scab at harvest, low-susceptibility cultivars were relatively less scabbed with only 3.1–46.5% of scabbed fruits. During years with low scab stress, it was very interesting to observe the almost total absence of the disease on the low-susceptibility cultivar, Reine des Reinettes, whereas on the susceptible cultivar, Gala, 40% of leaves and 22% of fruits were scabbed at harvest. These results confirm the interest of partial resistance for scab management in orchards. It is possible to take the level of susceptibility of cultivars into consideration within the framework of integrated fungicide protection against apple scab.

Keywords: Apple scab; *Venturia inaequalis*; Partial resistance; Integrated management

1. Introduction

Chemical control of apple scab caused by *Venturia inaequalis* (Cke) Wint represents a considerable part of the pest control measures necessary to protect an apple orchard when it is planted with one or several cultivars susceptible to the disease. In France, as many as 15–20 fungicide treatments per year may be necessary to control the disease, depending on the year and the region (Parisi et al., 2004b). These intensive treatments have a negative impact on the beneficial fauna and can lead to the development of certain pests (Mercier et al., 2000; Cuthbertson and Murchie, 2003), as well as to problems of resistance of *V. inaequalis* to some active ingredients (Szkolnik and Gilpatrick, 1969; Stanis and Jones, 1985; Parisi et al., 1994; Köller and Wilcox, 1999; Steinfeld et al., 2001; Remuson et al., 2007). Many unexplained failures to control apple scab have occurred in French apple orchards over the past few years (Anonyme, 2005; Giraud and Orts, 2006).

Within the framework of integrated fruit protection, it is therefore essential to more effectively control the disease while reducing the number and impact of fungicide treatments. Planting cultivars with total resistance to scab is therefore a possible solution. However, the main source of resistance to scab of these cultivars is provided by the *Vf* gene, and several strains of *V. inaequalis* virulent to this gene have been observed in Europe. The use of this monogenic resistance does not appear to be a durable solution (Parisi et al., 1993a, 2004a). Another possibility available to fruit growers is to plant cultivars with low susceptibility to apple scab (i.e., cultivars with a high level of partial resistance). This type of polygenic resistance is assumed to be more durable than monogenic resistance (Lespinasse et al., 2000). It is possible to reduce the number of fungicide applications in orchards on these low-susceptibility cultivars. For example, the integrated control

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scheme proposed by Olivier (1986) takes cultivar susceptibility, the inoculum present in autumn in the orchard and the intensity of the projection of ascospores into account. This integrated control scheme takes a contamination risk level according to Mills and LaPlante (1951) and completed by the "Angers" level (Olivier, 1986) as the treatment threshold. Applying such a scheme requires applications of curative fungicides. Lefeuvre (see Parisi et al., 2004b) has tested this integrated control scheme for 3 years in commercial orchards of the Loire Valley (France) and has proposed some adjustments. Its application to plots planted with low-susceptibility cultivars led to an average reduction of the number of treatments over 3 years of 67%, compared with plots planted with susceptible cultivars.

The classification of the main cultivars of apple in relation to their susceptibility to scab was established on the basis of surveys of fruit growers and technology and research institutes (Aldwinckle, 1974; Parisi et al., 1993b; Trillot et al., 2002). This classification is the result of visual observations over several years in commercial or experimental orchards treated with fungicides to control scab. Several studies on partial resistance to scab were conducted in apple orchards not treated with fungicides. These studies generally took place within the framework of cultivar creation programmes and involved research into genetic resources (Amorin, 1984; Hernandez Castillo, 1990; Kühn et al., 2003; Lateur and Populer, 1994; Quamme et al., 2005). Recent studies carried out on potted plants under controlled conditions made it possible to either assess overall susceptibility to different cultivars in terms of different strains/inocula of *V. inaequalis* (Laurens et al., 2004), or to identify the possible existence of race/cultivar interactions within the framework of partial resistances (Calenge et al., 2004; Parisi et al., 2004a; Tartarini et al., 2004).

The aim of our study was to evaluate the impact of planting cultivars with partial resistance on *V. inaequalis* epidemics. To do this, we observed the development of scab epidemics on different apple cultivars over several years in two experimental orchards not treated with fungicides to control apple scab.

2. Materials and methods

2.1. Experimental orchards

Two experimental orchards were planted in the Loire Valley (France), with a climate conducive to scab development.

The first orchard (Bois l'Abbé experimental orchard) was planted on an experimental INRA site in Beaucouzé (Maine et Loire; France) in March 1999, within the framework of the European DARE project (Durable Apple Resistance in Europe) (Lespinasse et al., 2000). This orchard included 20 apple cultivars ranging from high to low susceptibility to apple scab and including *Vf*-resistant ones. Treatments (cultivars) were replicated four times with a block design. Each block consisted of 20 plots, and each plot consisted of a row of six trees of the same apple cultivar. Plots were separated from each other by a tree of cultivar Gala (clone 4712). Each block was surrounded by a row of Gala trees (clone 4712), a cultivar considered to be "susceptible to highly susceptible" to apple scab and thus producing abundant inocula over the orchard in a homogeneous manner. In this experiment, six cultivars with different levels of partial resistance to apple scab were considered: (i) a cultivar referred to in this experiment as Gala (clone 4410—Mitchgala), (ii) Golden Delicious (clone 972), (iii) Fiesta (clone 4681), (iv) Reinette Clochard (clone 2361), (v) Colapuis (clone 7204) and (vi) Firiki (clone 8500).

The second orchard (La Rétuzière experimental orchard) was planted on an experimental INRA site in Champigné (Maine et Loire, France) in April 1999. It included three blocks with two plots each. Each plot consisted of 78 trees of the same cultivar laid out in six rows of 13 trees. The plots were surrounded by an alley and a hedge of plants that are not a host of *V. inaequalis*. The two apple tree cultivars studied in this experiment were Gala (clone 6889-Tenroy) and Reine des Reinettes (clone 2640).

The classification of these cultivars for their susceptibility to apple scab in France differs slightly depending on the authors. Nevertheless, we can consider that Gala and Golden Delicious are "susceptible to highly susceptible" to apple scab, that Fiesta is "moderately susceptible" to apple scab, and that Reinette Clochard and Reine des Reinettes are "low-susceptibility" cultivars (Parisi et al., 1993b; Trillot et al., 2002). The leaf susceptibility of these cultivars to Bois l'Abbé local inoculum was evaluated in greenhouse tests. High susceptibility to local scab inoculum was observed for Gala, Golden Delicious, Fiesta and Reinette Clochard, low susceptibility to local scab inoculum was observed for Colapuis and Firiki (Laurens et al., 2004).

The cultivars studied do not normally carry a still-active major resistance gene, and are therefore susceptible to the local scab inoculum (Laurens et al., 2004). The presence of the *Vg* gene in the Golden Delicious cultivar should not normally have an impact on scab epidemics in the Bois l'Abbé experimental orchard because a very large proportion of the local inoculum strains of this orchard are virulent to this gene (Bénaouf and Parisi, 2000; Parisi, unpublished data).

The orchards were managed according to the principles of commercial orchards in the Loire Valley. Trees were trained according to the Solaxe training system (Lauri and Lespinasse, 1999). Trees were planted 4 m × 1.5 m apart for the "Bois l'Abbé" orchard and 4 m × 1.25 m apart for the "La Rétuzière" orchard.

2.2. Orchard protection

Orchard protection was similar to that of commercial orchards in the Loire Valley, except for the fungicide