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Emergence of boscalid-resistant strains of *Erysiphe necator* in French vineyards

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Abstract

The grapevine powdery mildew *Erysiphe necator* (*E. necator*) is an obligate pathogen. Powdery mildew-diseased vines show an important reduction in plant size, winter hardiness and grape yield. Even a low-level infection with powdery mildew was shown to taint wine and ultimately reduce wine quality. For many years, succinate dehydrogenase inhibitor (SDHI) fungicides, mainly the new generation active ingredients (AIs) boscalid, penthiopyrad and fluopyram, have been widely used to control powdery mildew in grapevines. The repeated use of fungicides (mainly boscalid) has resulted in the emergence of resistant microorganisms such as *Botrytis cinerea* (*B. cinerea*). However, boscalid resistance was never observed in *E. necator*. In this study, a large-scale survey of French grapevine field populations of *E. necator* revealed many field populations with low sensitivity to boscalid. Single spore strains originating from collected resistant populations showed Half maximal effective concentration (EC50) values greater than 100 mg L^{-1}, and strains originating from boscalid sensitive populations showed EC50 values lower than 1 mg L^{-1}. The complete nucleotide sequences of the EnSdhB succinate dehydrogenase of sensitive and resistant single spore strains revealed that H242R and H242Y substitutions in the EnSdhB succinate dehydrogenase subunit conferred *E. necator* resistance to boscalid. No cross-resistance of *E. necator* strains bearing H242R and H242Y substitutions in EnSdhB succinate dehydrogenase to fluxapyroxad and fluopyram was noticed. Therefore, our results highlight the emergence of resistance to boscalid activity in French vineyards and warrant the need of the implementation of risk assessment strategies to maintain effective grapevine protection against powdery mildew.

Keywords: Powdery mildew; boscalid resistance; succinate dehydrogenase inhibitor (SDHI) fungicides; *Erysiphe necator*; fluopyram; fluxapyroxad

1. Introduction

Chemical fungicides have been used in agriculture over past decades to effectively control crop diseases and promote high yield and quality crops (Lara and Belbahri 2011; Alenezi et al*.,* 2017). Among these fungicides, succinate dehydrogenase inhibitor (SDHI) molecules have been used since the 1960s, with carboxin as the first marketed compound (Samaras et al*.,* 2016). With the new generation SDHIs, new molecules such as boscalid, penthiopyrad or fluopyram, providing a broad-spectrum of anti-fungal activity on various crops, SDHIs have become widely used in plant protection against different fungal pathogens (Gutierrez-Alonzo et al*.,* 2017). SDHI inhibits the activity of the enzyme succinate dehydrogenase (SDH), also known as succinate ubiquinone reductase or complex II in the mitochondrial electron transport chain, and blocks the ubiquinone binding site of the enzyme (Gutierrez-Alonzo et al*.,* 2017). SDH is a functional enzyme complex bound to the inner mitochondrial membrane and active in the electron transport chain by reduction of ubiquinone as well as in the citric acid cycle by succinate oxidation to fumarate. It is composed of four nucleus encoded subunit proteins