Fungicides as efficient tools in integrated control of grape powdery mildew *(Erysiphe necator)*

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1 Introduction

Control of grape powdery mildew (*Erysiphe necator)* by fungicides in an integrated approach is an important option if other tools are not sufficient for effective control. There are various fungicides registered for powdery mildew control with different modes of action, systemic activity, preventive or curative properties.

2 Resistance risk

However, the activity of fungicides can be impaired by acquired fungicide resistance after intensive use for many years. The risk for such a development of resistance is determined by the inherent risks of the fungus and the compound and by agronomic factors (Figure 1). FRAC classified *Erysiphe necator* as a pathogen with a moderate risk of development of fungicide resistance. Compounds which control grape powdery mildew can be classified as compounds with a low, medium or high resistance risk (Figure 2). The third factor, the agronomic risk includes the cropping system, measures taken to reduce disease pressure, the use of less susceptible varieties, resistance management strategies and more.

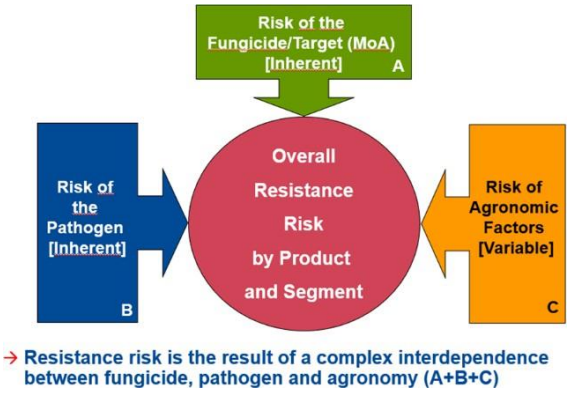

Figure 1: Factors determining the overall resistance risk. Pathogen risk and fungicide risk are inherent, agronomic factors are partially manipulable. Modified after Brent and Holloman (2007).

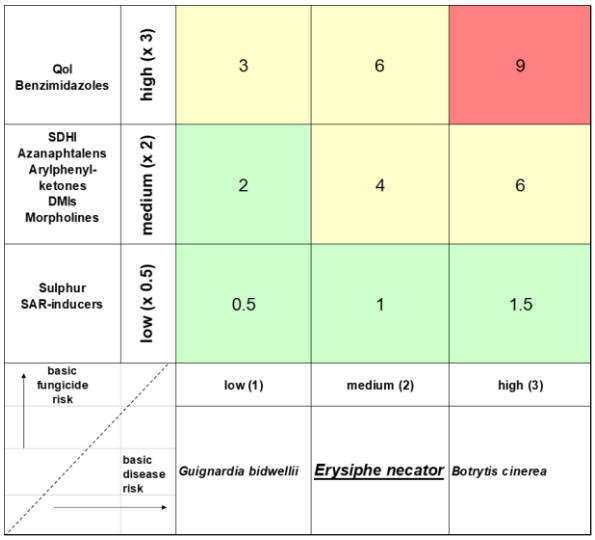

Figure 2: Matrix of the combined resistance risk (fungicide risk and pathogen risk) under unrestricted fungicide use. Combined risk is low for values 0.5-2, medium for 3 to 6 and high for 9. At medium and high risk, resistance management strategies are recommended. Modified after Brent and Hollomon (2007)

In the past, *E. necator* developed resistance to high risk QoI fungicides several years after intensive use of this mode of action (MoA) in grapes by the target site mutation G143A in the cytochrome *b* gene. This mutation leads to high resistance levels and affects field performance significantly if the majority of the field population carry this mutation. Resistance towards other modes of action such as aryl-phenyl-ketones or SDHIs have also been reported, but intensive monitoring studies in important grape growing areas show that most regions contain sensitive populations and that these modes of action are important tools for powdery mildew control.

3 Fungicide role in controlling grape powdery mildew

Another mode of action, the sterol biosynthesis inhibitors have been launched more than 40 years ago and play still an important role in control of grape powdery mildew. SBIs inhibit the ergosterol biosynthesis, which is an essential pathway in ascomycetes and basidiomycetes. Based on the enzyme targets in the ergosterol biosynthesis, SBIs can be divided in demethylation inhibitors (DMIs), amines

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(morpholines), keto reductase inhibitors (KRIs) and squalene epoxidase inhibitors. The last one is of minor importance in control of plant pathogenic fungi, KRIs are important fungicides for control of e.g. *Botrytis cinerea* and some compounds belonging to DMIs and morpholines have been developed for control of grape powdery mildew control. DMIs and morpholines are classified by the Fungicide Resistance Action Committee (FRAC) as compounds with low to moderate resistance risk (Figure 2). Adaptations to these modes of action have been detected in a limited sense and over a long time period. These adaptations are often gradual, where different adaptation mechanisms might result in an additive manner, what leads to the so called "shifting" phenotype.

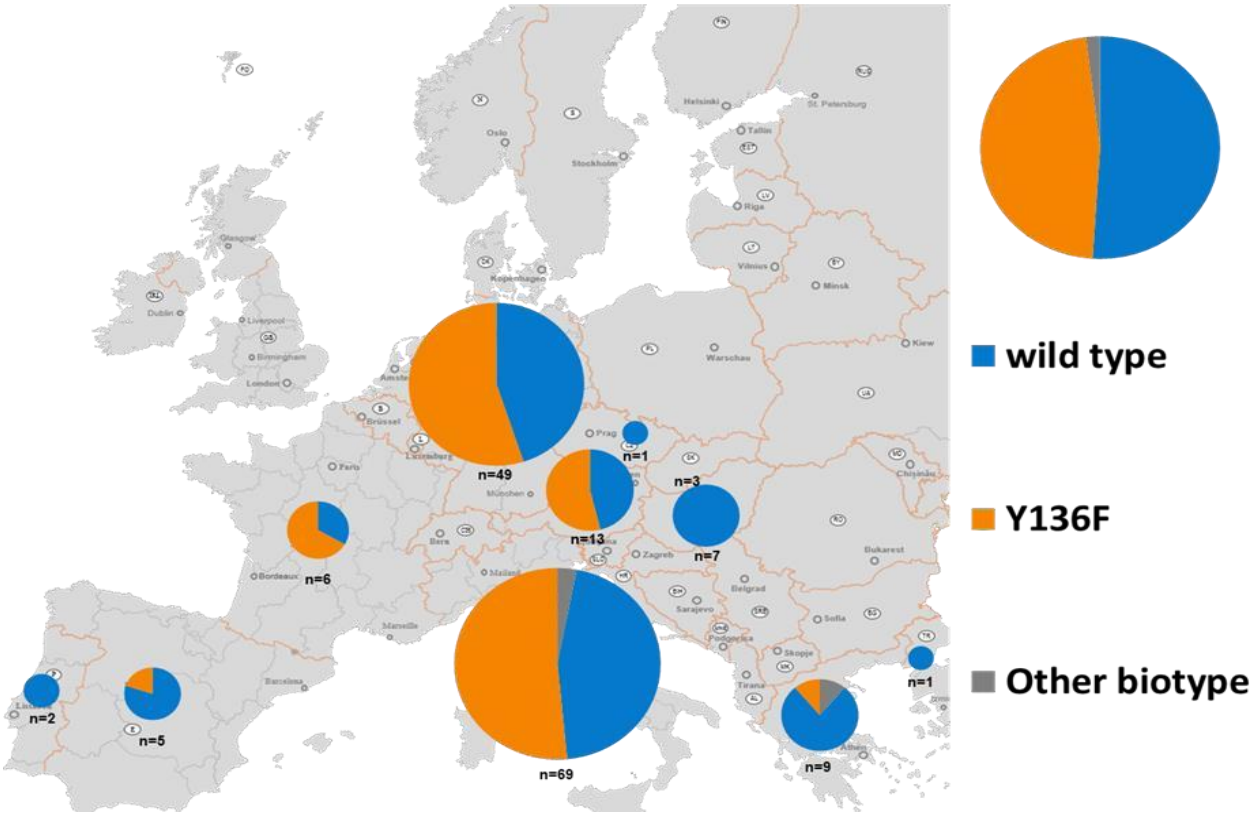

Figure 3: Frequency of the Y136F mutation in populations of *E. necator*, splitted by countries (data from 157 populations from 2016 and 2017)

For DMIs the target enzyme is the C14 demethylase, also called cyp51. In grape powdery mildew, a gene amplification of the cyp51 gene, which might lead to a target site overexpression (Jones et al. 2014) and especially the target site mutation Y136F (Delye et al. 1997) play an important role in the reduction of sensitivity to some DMIs. Around 50% of the current European grape powdery mildew population carries the Y136F in the cyp51 gene (Figure 3). Interestingly, DMIs might be differently affected by this mechanism. A new DMI, mefentrifluconazole has been developed for control of DMI shifted populations of grape powdery mildew. Sensitivity studies showed that this new DMI is not significantly affected by the Y136F mutation and therefore highly efficacious for grape powdery mildew control (Figure 4). The high control efficacy of mefentrifluconazole combined with a medium resistance risk and its favourable regulatory profile makes this fungicide an important tool for disease and resistance management ofgrape powdery mildew, especially in integrated control approaches.

To avoid or delay the occurrence shifting or resistance to all MoA and to keep frequency of resistant isolates at low levels, effective resistance management strategies are necessary. It is important to limit the number of applications of a specific MoA, consider the use of effective mixtures with different MoAs and to alternate between MoA. All measures, which lower the disease pressure and therefore the selection pressure need to be implemented. For a sustainable resistance management, it is important that various MoA are available. This includes also the use of fungicides with "multi-site activity", like sulphur.

There are a lot of data available at the FRAC webpage (www.frac.info) and the authors recommend to follow the recommendations for the use of the different modes of action, which are published and yearly updated in the chapters of the different FRAC Working Groups**.**

4 Conclusions

Taking into account the risk of resistance that fungicides may cause, they remain a viable option in integrated pest

management. Fungicides indeed are strategic when other tools are not sufficient for effective control.

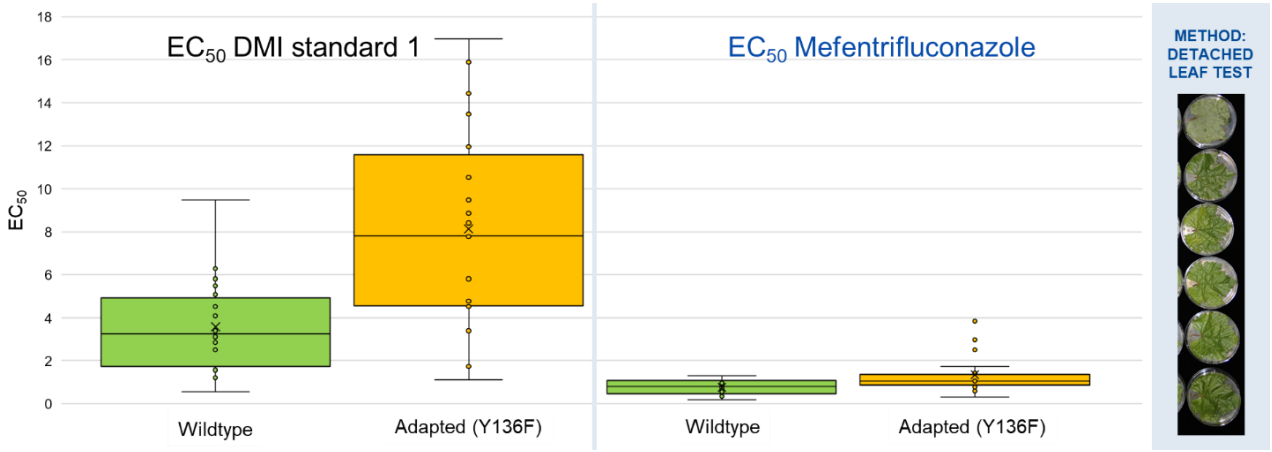

Figure 4: Sensitivity of wildtype (n=22) and Y136F (n=24) cyp51 haplotypes towards mefentrifluconazole and a standard DMI. EC_{50} values were detected by a detached leaf test.

References

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