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A critical review of plant protection tools for reducing pesticide use on grapevine and new perspectives for the implementation of IPM in viticulture

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ABSTRACT

Several pests and diseases have grapevine as their favourite host and the vineyard as preferred environment, so an intensive pesticide schedule is usually required to meet qualitative and quantitative production standards. The need to prevent the negative impact of synthetic chemical pesticides on human health and the environment and the consumer expectations in term of chemical residues in food stimulated the research of innovative tools and methods for sustainable pest management. The research project PURE (www.pure-ipm.eu) was a Europe-wide framework, which demonstrated that several solutions are now available for the growers and evaluated several new alternatives that are under development or almost ready for being applied in practice. Although the use of resistant/tolerant varieties is not yet feasible in several traditional grape growing areas, at least part of the synthetic chemical pesticides can be substituted with biocontrol agents to control pests and pathogens and/or pheromone mating disruption, or the number of treatments can be reduced by the use of decision support systems, which identify the optimal timing for the applications. This review presents the state of the art and the perspectives in the field of grapevine protection tools and strategies.

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1. Introduction

Grapevine is one of the most important crops worldwide, in relation to the production of both wine and table grapes. Several pests and diseases may affect grapevine, so an intensive pesticide schedule is often required to meet production standards. Precise quantification of the synthetic chemical pesticides used for the grapevine is not available and the quantities can be highly variable in different years and locations, depending on the relative

importance of each pest and pathogen. In general, fungicides account for the largest share of pesticide treatments in most vineyards (with an average of 12–15, up to 25–30 applications in the most problematic conditions; for example see for Italy <http://www.istat.it/it/archivio/15004>).

Since their introduction from America in the 19th century *Plasmopara viticola* (the causal agent of downy mildew) and *Erysiphe necator* (the causal agent of powdery mildew) represent the most important grapevine diseases, and together with *Botrytis cinerea* (the causal agent of grey mould) account for the largest number of treatments in vineyards. Another pathogen originating from North America *Phyllosticta ampelica* (syn. *Guignardia bidwellii*), which is the causal agent of black rot, occasionally causes damage, especially

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in vineyards that are pruned and harvested mechanically or located closely to abandoned infested vineyards, because the pathogen overwinters on berry mummies, which may remain on the plants. *Phyllosticta ampellicida* does not usually require additional treatments, because chemical protection against powdery and downy mildews is sufficient to prevent black rot, although in recent years, especially because of increased use of active ingredients specific against oomycetes and the adoption of downy mildew resistant varieties, its importance is increasing. Other diseases such as cane blight (*Phomopsis viticola*) and leaf spot or “rotbrenner” (*Pseudopezizica tracheiphila*) appearing occasionally or in specific geographical locations, do not require an extensive fungicide schedule, but rather better timing of treatments against the main grapevine pathogens (Nita et al., 2006; Reiss and Zinkernagel, 1997).

Grapevine trunk diseases (GTDs) are a recent threat to viticulture sustainability. Wood diseases have always affected tree crops, but their recent spread and the increase in severity worldwide (Mugnai et al., 1999; Bertsch et al., 2013) are probably the result of environmental changes and undoubtedly related to the way we have been growing grapevines in the last century (Surico et al., 2004). Grapevine trunk diseases, which affect the main trunk and cordons, include canker caused by Botryosphaeriaceae or Diatrypeaceae fungal pathogens (such as *Eutypa dieback*) and are becoming increasingly important, along with black foot disease (caused by *Dactylonectria* and *Ilyonectria* species), which typically affects the roots and collars of young vines. The most common and damaging GTD in Europe is a complex of diseases – the esca complex – involving vascular fungal pathogens, decay agents and their likely interaction with canker pathogens. It is worth mentioning that interaction between multiple pathogens, including their virulence factors (indeed many of them produce active phytotoxins), and the physiological status of the plant in GTDs is crucial for the development of the disease (Fontaine et al., 2016).

Pesticide use against grape arthropods is usually low to moderate (1–4 insecticide applications per year), except for table grape production (up to 8–10 insecticide applications per year). Insecticide overuse is often associated with toxicological and environmental problems, and neurotoxic insecticides or insect growth regulators in particular are suspected of causing human diseases (Fantke et al., 2012). As a consequence, such products have been banned in the European Union (Karabelas et al., 2009). Resistance to insecticides and acaricides is a major concern, although in viticulture this problem was more frequent for fungicides. Pest resurgence and pesticide-induced pests have represented additional implications of insecticide use in viticulture (McMurtry et al., 1970; Duso et al., 2012). Spider mite (in particular *Tetranychus urticae* and *Panonychus ulmi*) outbreaks after the Second World War have been claimed to be a consequence of insecticide use (e.g. chlorinates, organophosphates and carbamates), and recent problems with scales (e.g. *Parthenolecanium corni*) are considered to be another example of this phenomenon. The occurrence of new pests is another concern for European viticulturists. In the last 15 years, two leafminers (*Phyllocnistis vitegenella* and *Antispila oinophylla*) and a leafhopper (*Erasmoneura vulnerata*) have been detected in northern Italy. Recent findings suggest that the impact of some pests will increase with increasing temperatures (Reineke and Thiéry, 2016).

Problems associated with old synthetic chemical pesticides and consumer demand for residue free products have stimulated research into new tools for pest management. Chemical companies are developing new active substances with a favourable profile for human health and the environment, and new mechanism of action with lower risk of developing resistant pest populations. Alternatives to synthetic chemical pesticides are represented by a number

of microbial and botanical active ingredients and pheromone-based tactics in the case of insecticides alone. Inoculative and inundative biocontrol techniques (e.g. release of predators or parasitoids commercially produced by biofactories) against insect pests have been less investigated in vineyards than in other agricultural systems such as greenhouse vegetables and ornamental plants. In contrast, conservation biocontrol strategies have attracted the interest of researchers in order to successfully manage various pests, mainly grape berry moths and leafhoppers.

A drastic change in the grapevine cropping system (for example the use of insect proof nets or plastic covers and tunnels along the rows, etc.) is unlikely to happen in Europe, for economic (e.g. traditional varieties are used for the production of most of the more profitable wines) and environmental reasons (e.g. high visual negative impact on the traditional landscape). Therefore, the growers should combine several different tools in order to reduce the input of synthetic chemical pesticides on this crop. Agronomic practices, i.e. reduction of the inoculum or improvement of the microclimate of the plant in order to avoid conditions favourable to pests and diseases, are commonly implemented in most of the grape growing areas. Resistant/tolerant varieties may represent a solution to reduce fungicide treatments, however their implementation is widely limited by the market, especially for wines produced in typical areas (e.g. AOC in France, DOC and DOCG in Italy). Biopesticides based on microorganisms or natural molecules may represent an alternative to synthetic chemicals, however several of existing solutions have drawbacks or limiting factors, which prevent a fast uptake by the farmers (Lamichhane et al., 2016). On the contrary, beneficial arthropods and the use of semiochemicals may offer interesting and sustainable alternatives to synthetic chemical pesticides in certain contexts. Due to all these reasons, the correct timing of the synthetic chemical application is still a crucial step to achieve a sustainable use of pesticides.

Differently from annual crops and other perennial fruit crops, in most of the traditional growing areas grape production cannot benefit from crop rotation or a radical change of the cropping system. Therefore the IPM toolbox includes: the use, wherever possible, of resistant/tolerant varieties, the substitution of the synthetic chemical pesticides with biocontrol agents against pathogens, arthropod pests and disease vectors and/or the use of semiochemicals and physical mating disruption. When substitution with alternatives is not possible, mathematical models and monitoring can help in optimising the pesticide applications. The alternatives to herbicide use are cover cropping and tillage.

2. Possible solutions offered by resistant/tolerant varieties

2.1. Downy and powdery mildew resistant/tolerant *Vitis* hybrids or varieties

Since the end of the 19th century, after the introduction of *P. viticola* and *E. necator* from America to Europe, growing traditional *Vitis vinifera* varieties has no longer been possible without considerable fungicide applications. Initial efforts in Alsace (France) to breed new disease-resistant varieties by crossing resistant American *Vitis* species with traditional European *V. vinifera* led to fairly resistant hybrids, which, however, often produced an undesired off-flavour in wine (foxy taint). According to Töpfer et al. (2011), planting of such hybrids in large areas led to a decrease in wine quality in those areas. Thus, consumers often associate resistant varieties with off-flavours and poor wine quality. A small number of breeding programmes in Europe have continued crossing hybrids with *V. vinifera* varieties in order to obtain resistant varieties with the traditional flavours that consumers are used to. Breeding techniques have evolved radically over time (Töpfer et al.,

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