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Review

Fungus resistant grape varieties as a suitable alternative for organic wine production: Benefits, limits, and challenges

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ABSTRACT

Areas dedicated to organic wine production have significantly increased over the last few years. The vast majority of organic wine is made from *Vitis vinifera* varieties that are highly susceptible to fungal diseases and pests, making organic management difficult for growers. Depending on the growing area, 20–70% of organic growers declare issues with fungal diseases in Europe. Recently, fungus-resistant grape (FRG) varieties have been recommended as the most suitable choice in organic viticulture, especially in areas where disease pressure necessitates high rates of fungicides. FRG varieties could contribute to improved disease management in organic as well as conventional viticulture, reduce production costs and decrease copper accumulation in soils. Recently, many FRG varieties presenting advantageous agronomic attributes and enological characteristics have been developed in North America and Europe for conventional and sustainable farming. In this review, we present an overview of the benefits and limits associated with FRG varieties in addition to the current knowledge regarding berry and wine composition, canopy management, and winemaking challenges and practices.

Contents

Abbreviations: FRG, fungus resistant grape; M3GE, malvidin-3-glucoside equivalents; MDGE, malvidin-3,5-diglucoside equivalents; DW, dry weight; FW, fresh weight; LC–MS/MS, liquid chromatography coupled to mass spectrometry; UPLC–MS, ultraperformance liquid chromatography coupled to mass spectrometry; HPLC-DAD, high performance liquid chromatography coupled to diode-array detector; CE, catechin equivalent; B2E, procyanidin B2 equivalent; RE, resveratrol equivalent; TA, titratable acidity; TSS, total soluble solids; YAN, yeast assimilable nitrogen.

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1. Introduction

Organic wine production considerably increased over the last ten years and accounts for nearly 5% of total production of today's wine market (Bonn et al., 2015; Willer and Lernoud, 2015). Reasons driving consumers toward organic wine varies from health concerns to environmental awareness and interest for *terroir*, and the overall perception that organic wines are of higher value than conventional ones (Bonn et al., 2015).

Organic wines are expected to be free of synthetic pesticides, fertilizers or other synthetic inputs that could pose a higher risk than conventional farming to human health or the environment (Mann et al., 2010; Bonn et al., 2015). However, the vast majority of organic wine is made from *Vitis vinifera* varieties highly susceptible to fungal diseases and pests, making organic management difficult for growers (Wiedemann-Merdinoglu and Hoffmann, 2010). Depending on the country origin, 20–70% of organic growers declare issues with botrytis and powdery mildew in Europe (Collective, 2008).

In contrast with conventional viticulture that integrates a wide range of synthetic pesticides in pest management programs, organic viticulture mostly relies on sulfur- and copper-based fungicides such as the Bordeaux mixture to control major diseases like downy and powdery mildews, as well as a wide range of other diseases and insect pests (Provenzano et al., 2010). Copper-based formulations have been used for more than a hundred years in European vineyards (Flores-Vélez et al., 1996), but copper has a low mobility in soil and was later found to accumulate to levels that could threaten the environment (Komárek et al., 2010). Indeed, copper concentration is typically much higher in vineyard soils (20–665 mg/kg) compared to arable land (5–30 mg/kg) (Besnard et al., 2001; Komárek et al., 2010). Such accumulation is likely to occur in perennial crops like grapevines because copper fungicides are continuously sprayed on the same land (Komárek et al., 2010). Correspondingly, vineyards located in wet areas show higher copper concentration than those from dry areas, which suffer less pressure from diseases (Komárek et al., 2010). Copper concentration reached 93 mg/kg in the 0–20 cm soil layer of a Mediterranean organic vineyard with a dry climate, whereas values between 200 and 297 mg/kg have been reported in conventional vineyards located in wet areas from Northern Italy (Provenzano et al., 2010).

The European Union recently established premium goals to reduce pesticides, particularly copper, in viticulture (Rousseau et al., 2013). One of the strategies is to shift from a treatment-oriented approach to a disease prevention approach by the development of fungus-resistant varieties (Rousseau et al., 2013). Fungus-resistant grapes (FRG) result from interspecific cross-breeding between the Mediterranean species *V. vinifera* and North American and Asian *Vitis spp*. such as *V. riparia*, *V. amurensis* and *V. rupestris* that carries high resistance to fungal diseases, including powdery and downy mildews, and grey rot. The firsts FRG varieties, issued from traditional breeding, carried a significant percentage of non-*V. vinifera* species in their genetic and were therefore considered as “interspecific hybrids” (Sivčev et al., 2010). Recently, marker-assisted selection combined with multiple backcrossing with *V. vinifera* varieties allowed the development of FRG carrying both disease-resistance genes and a significant percentage (more than 85%) of *V. vinifera* in their pedigree; those are generally referred to as “PIWI” (from German: *Pilzwiderstandsfähige*, “disease resistant”) and are accepted as *V. vinifera* varieties in European catalogues (Sivčev et al., 2010). In some cases though, “PIWI” indistinctly refers to both interspecific hybrids and newer “disease-resistant *V. vinifera*” varieties (Collective, 2008; Siegfried and Temperli, 2008).

Optimal variety selection is a key factor for successful implementation of organic grape production (Fragoulis et al., 2009; Sivčev et al., 2010). Recently, FRG varieties have been recommended as the most suitable choice for organic viticulture (Pavloušek, 2010; Sivčev et al., 2010; Becker, 2013). Resistance to major diseases such as powdery mildew significantly reduces the need for pesticides and thus represents a major advantage in organic farming, especially in humid areas such as Bordeaux (Galbrun, 2008; Sivčev et al., 2010; Wiedemann-Merdinoglu and Hoffmann, 2010; Fuller et al., 2014; Weigle and Carroll, 2015).

Superficies devoted to organic wine production from FRG varieties are not well documented. In Germany, FRG occupied 7.9% of organic vineyard surface areas in 2003 but projections were that 40% of the new plantings planned from 2010 to 2015 would be FRG cultivars (Sloan et al., 2010). In contrast, both old and recent FRG varieties have spread extensively over the last 30 years in areas presenting challenging growing conditions such as wet summers and cold winters with most of these varieties grown using conventional management practices (Table 1). Very little research has been done to compare vineyard practices and pesticide use for FRG varieties grown under conventional vs. organic management. In addition, the large genetic pool found in FRG varieties makes them highly variable in terms of viticulture (e.g., vigor, canopy management, berry ripening), berry composition (e.g., sugars, acids, phenolic compounds) and winemaking (e.g., aroma). In order to obtain a comprehensive understanding of FRG varieties with regards to organic grape production, this review will present the benefits and limits of FRG for organic wine production, present their agronomic and oenological characteristics, and discuss challenges related to their use in wine production.

2. Benefits and limits of FRG in organic viticulture

2.1. Breeding for disease resistance and quality

In phytopathology, “resistance” refers to the capacity of the plant to defend itself against pathogens (Prell and Day, 2001). Interspecific hybridization of grapevines began in the 19th Century and was initially aimed at introducing pest and disease resistance in offspring (Galet 1999; Avenard et al., 2003; Reynolds, 2015). Many FRG developed at that time carried undesirable “foxy” flavors in their wine, a default that was later attributed to the presence of *V. labrusca* in the breeding process, resulting in the near elimination of this species in recent breeding (Hemstad and Luby 2000; Sun et al., 2011a). Later, several breeding programs implemented worldwide led to the development of varieties showing different characteristics such as cold-hardiness, short/long growing season, and pest resistance (detailed review by Reynolds, 2015).