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The organic vineyard as a balanced ecosystem: Improved organic grape management and impacts on wine quality

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ABSTRACT

Worldwide interest for organic farming increased significantly since the last decade. Wine makes no exception to this trend, as consumer demand for organic wines and environmental friendly viticulture practices increases. Organic wine production aims at producing high quality grapes and wines while minimizing the use of inputs, both in the vineyard and the winery. Its success lies in an approach that takes advantage of the biodiversity to maintain a balance between resource availability, living organisms and productivity in the vineyard, while maintaining pest and disease at the lowest level. In this review, we will present management practices for successful grape production under organic management, including methods for disease and pest prevention, and treatments in the vineyard. Then, we will review the impact of organic grape management on the quality of organic wine.

1. Introduction

Conventional viticulture is among the most pesticide-consuming agricultural systems (Aubertot et al., 2005). For example, grape production in France occupies less than 3% of the total area devoted to agriculture and consumes nearly 20% of total pesticides (Aubertot et al., 2005; Delière et al., 2014). In Italy, more than 200 different pesticides are registered for grapevine (Cabras and Conte, 2001). The intensive use of pesticides triggers the build-up of pest systemic resistance (Leroux et al., 2002; Savocchia et al., 2004) and negatively impacts non-targeted organisms including fauna, plants, and microbiota (Hildebrandt et al., 2008; Komárek et al., 2010; Nash et al., 2010). In this context, the reduction of pesticide in viticulture and higher deployment of organic viticulture become highly valuable.

From 2002 to 2013, areas devoted to organic grape production significantly increased (Table 1). Representing 4.6% of the total grape production, in a total of 310 000 ha, the three most important producing countries are Spain, France and Italy (Willer and Lernoud, 2015). Although Europe owns 90% of the total cultivated area, organic grape production recently expanded in other countries such as China and Turkey (Willer and Lernoud, 2015). Despite these significant expansions, several factors may have slowed down the progression of organic viticulture, including unreliable yields, issues with pest management, and the need to educate consumers in organic products (Willer et al., 2008). Consumers either have a negative perception of organic wines quality, or are not willing to pay higher cost generally attached to these wines (Iordachescu et al., 2009; Ogbeide, 2015; Rojas-Méndez et al., 2015). In addition, crop yield may be reduced by 8–16% compared to conventional grapevines (Bayramoglu and Gundogmus, 2008; Guesmi et al., 2012). Therefore, the challenge of organic wine production is significant: organic growers and winemakers are expected to produce wines using pesticides and inputs chosen from an approved list while maintaining the high quality requested by consumers.

Success in organic viticulture is mainly based on implementing a production system that minimizes the incidence of disease and pest and consequently reduce the use of pesticides such as copper-based fungicides, without compromising crop productivity (Sivčev et al., 2010). A successful approach is to consider the vineyard as an ecosystem where every resource is optimized to maintain a

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Table 1
Worldwide progression of areas devoted to organic grape production 2002–2013 and conventional grape production (2012–2013).

Country	Area under organic production (ha)												Total cultivated area (ha)
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2012–2013
Argentina											5 359	4 139	221 000
Austria	1 114	1 536	1 657	1 791	1 766	2 477	2 773	3 218	3 863	4 178	4 259	4 414	43 700
Canada							112	129			262	347	11650
Chile											4592	3 595	205 000
China											2 000	19 174	570 000
France	15 013	16 259	16 428	18 133	18 808	22 509	27 869	39 146	50 268	61 056	64 801	64 610	800 000
Germany						3 500	4 400	4 700	5 200	6 900	7 400	7 100	100 000
Greece	2 599	3 168	3 303	3 955	4 603	4 561	5 024	4 875	5 001	4 807	4 997	4 718	110 000
Italy	37 379	31 709	31 170	33 885	37 694	36 684	40 480	43 614	52 273	52 812	57 347	67 937	769 000
Portugal	575	839	1002	1 240	1 178	2 021	2 028	1 804	2 667	2 523	2 523	2 523	239 000
Spain	16 038	16 453	14 928	15 991	16 832	17 189	30 856	53 959	57 232	79 016	81 262	83 932	1 018 000
Turkey											6 571	8 418	517 000
United States	5 088			9 226			11 448			15 646	15 647	15 647	394 000
Total	77 806	69 964	68 488	84 221	80 881	88 941	124 990	151 445	176 504	226 938	257 020	286 554	4 998 350

Sources: (European Commission, 2013; Karlsson, 2014; Macey, 2010, 2011, 2012; USDA, 2015a; Willer, 2008; Willer and Yussefi, 2006; Willer and Lernoud, 2014, 2015).

rich biodiversity contributing to decrease pest and disease pressure (Thies and Tscharntke, 1999). Such crop production systems largely differ from conventional production and may therefore have several impacts on wine composition and quality, possibly justifying the high price of organic wines (Rojas-Méndez et al., 2015). In this review, we will present how an approach based on biodiversity can contribute to preserve the organic vineyard ecosystem for successful organic grape production, present certain techniques and products used in organic growing, and report recent studies on the impact of organic viticulture on wine quality.

2. The organic vineyard as a balanced ecosystem

A balanced ecosystem is defined as a diversity of organisms, such as fauna, plants and microorganisms, living in complementarity in a competing system (Begon et al., 1996). In natural ecosystems, a rich biodiversity prevents the domination of a single species over the others (Thies and Tscharntke, 1999). In contrast, the vineyard is a monoculture that artificially favors a perennial species (e.g. grapevine) over the others, a balance that is maintained through the use of synthetic pesticides in conventional viticulture. Conversely, organic viticulture aims at reducing the use of approved pesticides by adopting different practices that promotes an adequate biodiversity within the production system.

Increasing the presence of beneficial organisms that maintain enemies at under control contributes to preserve the balance between the main crop and the other organisms (Thies and Tscharntke, 1999). The success of this approach is based on three key elements: (i) manage resources availability by improving soil structure, and controlling competition and crop attractiveness; (ii) improve arthropod diversity to constraint grapevine enemies and (iii) prevent diseases using optimal canopy management practices (Rombourgh, 2002).

2.1. Resources management

2.1.1. Maintain or improve soil structure

Soil is considered as an interactive system in which its structure, flora, fauna, and organic matter are strongly interrelated (Coleman et al., 1992). In organic vineyard, cultural practices, such as mulches, cover crops, organic enrichments and cultivation, are recognized to modulate soil structure and composition. Mulches help to rebuild the soil food web after the vine plantation (Rombourgh, 2002).

When resources like water are not limited, cover crops (CC) may provide additional organic matter and significantly contribute to improve soil quality (Adams, 2011; Ingels et al., 2005; McGourty and Reganold, 2005; Wheaton et al., 2008). Under organic management, CC and organic matter inputs generally have a positive impact on earthworms by increasing their abundance and biomass (Pérès et al., 1998). However, Coll et al. (2011) showed that the density and biomass of earthworm decreased in organic vineyard without organic matter inputs, while the biomass of soil microorganisms and the nematofauna were found to increase. CC are also known to increase microbial communities in cover cropped vineyards when compared to disk control, but the CC species does not impact the composition of the microbial community (Ingels et al., 2005).

2.1.2. Control competition: weeds, cover crops and grapevine

Weeds are plant species showing excessive growth and high adaptation to their growing environment. Unlike CC, they are aggressive, hardly manageable, and compromise vineyard productivity by competing with the vines (Wisler and Norris, 2005). The use of synthetic herbicides is prohibited in organic viticulture. Therefore, mechanical removal remains the primary option to control weed growth under rows, whereas CC are a proper option between rows (Pimentel et al., 1992; Sanguankeo et al., 2009). Early establishment of aggressive CC species, such as wheat and rye, or use of spring-planted plots, are the best strategies to decrease weed growth, biomass and density, without negative impacts on vine (Bordelon and Weller, 1997; Krohn and Ferree, 2005). Some CC species are better competitor (e.g. rye, wheat, barley, oats) than other (e.g. vetch) while others use allopathic effects (e.g. rye), so their potential for weed competition and suppression varies (Bordelon and Weller, 1997; Putman et al., 1986).

Competition for water and mineral resources has a direct impact on vine vigor, even when this competition comes from CC rather than weeds. In fact, lower pruning weights and shoot length, fewer lateral shoots and higher canopy openness have been observed in cover cropped vineyards (Ingels et al., 2005; Krohn and Ferree, 2005; Tesic et al., 2007). When resources are not limited (e.g., fertile soil, high water availability), such competition may improve vine balance by reducing excessive vigor and potentially improve crop quality without significant impact on yield (Giese et al., 2015; Ingels et al., 2005; Sweet and Schreiner, 2010; Wheeler et al., 2005). In contrast, long-term cover cropping is restricted in areas where water availability is limited (Guerra and Steenwerth, 2012).

Success with CC lies in proper selection of species and management methods to maximize the benefits and reduce potential problems (Guerra and Steenwerth, 2012; Ingels et al., 2005, 1998). Indeed, species such a clover, rye, ryegrass and fescue have been largely tested in viticulture and prove to be efficient in many countries (Guerra and Steenwerth, 2012). Yet, other factors may affect