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Organic Vineyard: Yeast Diversity, Biogeography, and Prospects for the Future

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Introduction

Serious research over the last two decades on microbial diversity has generated dazzling conclusions for its potential applications towards a new future. Among them, the vineyard has been shown to be a potential reservoir of microbiological biodiversity. In particular, the vineyards cultivated in an organic production system are responsible for a higher yeast diversity than conventional vineyards. This great diversity of yeasts (but also of other fungi and bacteria) has potential uses not only as a tool for exploitation, for example, in the oenological field, but also in the industrial sector and even in solving problems such as mitigating the effects of climate change or wastewater purification. Moreover, in recent years, it has been shown that yeast biodiversity is highly associated with its geographical location, introducing the concept of microbial terroir or biogeographical patterns of yeasts. And more recently even the relationship of NDVI (Normalized Difference Vegetation Index) taken at satellite level has been correlated with regional yeast diversity. All this opens the door to exciting discoveries with new and encouraging perspectives for the future, which is why the microbial biodiversity of organic vineyards is a valuable reservoir that needs to be preserved. Nowadays there is a global trend towards an increase in organic vitiviniculture which is of great importance not only in environmental terms but also as a generator of added value. These practices contribute to obtain more sustainable and healthy products. World organic production is increasing considerably year by year, especially in vineyards, which is the main crop in organic production. European countries such as Spain lead the ranking of the largest surface area of organic vineyards Hole et al. [1]; Willer & Lernoud et al. [2] and the European Union has stated in the Horizon 2030 that the European Union should have 25% of its agricultural surface area cultivated under the organic production system. In addition, recently, since January 1, 2022, the new Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007 is in force REU 2018/848, [3].

Microorganisms are the most abundant living beings on Earth with a central role in basic ecological processes of the ecosystems. Therefore, their diversity must be conserved. Organic vineyard production requires specific agronomic practices, techniques of soil management, fertilization and pest control that differ from conventional production. Yeasts are essential in fermentation, winemaking, and other industrial processes because their knowledge plays an important role in the differentiation of the final product and to solve new problems. On the other hand, has been shown that organic production has an influence on the yeast diversity of grapes and wineries and that the organic vineyard is a great reservoir of this different yeast species Agarbati et al. [4]; Bagheri et al. [5]; Drumonde NJ et al. [6]; Thompson et al. [7].

Organic farming leads to an increase in the yeast population of musts at quantitative and qualitative level. Most organic samples owned higher yeast species richness; some of

them with oenological relevance. Therefore, organic vineyards are important reservoirs of yeast diversity. Since the different species of yeast found in the vineyard, it has been shown the influence of the culture system (organic versus conventional) on chemical characteristics of musts. In addition, as yeasts are living beings, they change with the year affected by climatic conditions and cultural practices Castrillo et al. [8]; Cordero B et al. [9]; Grangeteau et al. [10]. Likewise, organic vitiviniculture is reinforced with the use of native cultivars adapted to edaphoclimatic conditions and native yeasts, which are better adapted to the particular must conditions and winery environment of each region Bokulich et al. [11]. Global and dominant yeast species (*Aureobasidium spp*, Metschnikowia spp., Hanseniaspora uvarum and *Cryptococcus spp*) were similar around the world and culture systems. Conversely, other species are ubiquitous, such as Candida spp. *Lachancea thermotolerans*, Starmerella bacillaris, etc., and show great variation in each region. In addition, these minor yeast species are also influenced by year, grapevine variety or anthropic conditions Drumonde NJ et al. [6]; Hranilovic et al. [12]. Then, richness and proportion of yeast species was mainly influenced by geographical location. These different biogeographic patterns of yeasts or microbial terroir concept, allows high quality in the fermentation products while preserves their typicality and uniqueness, characteristics that are especially appreciated in organic production Castrillo et al. [13]. Therefore, study of native yeast communities of vineyards and wineries, particularly in organic production, is an important step towards the preservation of the native genetic resources. Induced used of the same microbial strains generate a large replacement of native yeasts and result in the loss of identity, but native strains can lead solve current and future problems, not yet generated. The production system also influences the healthy characteristics and differentiation of wine and fermentation products, which directly affects the assessment of consumers from a socioeconomic perspective Callejon et al. [14]. The most recent research focuses on mitigate the effects of climate change Castrillo et al. [15]; Morata et al. [16]; Sancho G et al. [17], microbial interactions Englezos et al. [18]; Oro et al. [19] and others delve further, in multidisciplinary terms. The NDVI (Normalized Difference Vegetation Index) calculated from Landsat 8 imagery was used to perform a spatio-temporal analysis (a three-year study) of several vineyards belonging to four different Appellations of Origin (AOP). This work suggested that satellite imagery can establish differences in terroir; the higher the NDVI, the higher the yeast species richness; the relationship between NDVI, terroir, and yeasts shows a stable trend over the years Vélez et al. [20]. More than 100 different genera of yeasts are known; these and other new conclusions derived from the hypotheses currently launched in current research open the door to new perspectives for the future. Further research is required on the application of the large collection of native yeast strains of S. Cerevisiae and non-Saccharomyces identified which may have great oenological potential. The fermentation of mixtures (fruit, vegetable, flower, and cereal malt juices together) in mixed or sequential co-inoculation of one or even several yeast and bacteria species S. cerevisiae/non-Saccharomyces and the knowledge about their interactions and biocontrol activity is fascinating. For example, Brettanomyces yeast is spoilage in wine and favorable in beer; it could provide technical solutions and surprising results improving quality and new products typicality. Likewise, the behaviour of these combinations, should be studied together with new strains of bacteria as lactic acid bacteria (BAL) including species such as Lactobacillus plantarum, in line with new challenges and demands (palliate the effects of climate change, production of organic or special fermentation products, etc.). Justified optimal results would need to be studied on an industrial winery scale to verify their behaviour and real viability. And even conclude with the marketing of the strains with the best differentiated oenological aptitude. Finally, this can economically stimulate the production of organic vineyards that maintain the regional yeast diversity and the wine particularity. But also, this natural reservoir of diversity is a valuable resource with potential use even in non-oenological fields. In this sense, non-Saccharomyces yeast strains have been found useful for mitigating the effects of climate change on fermentations. But the application of the new yeast strains goes further. For example, species never before cited as inhabitants in wine-related environments are being researched for use in biochemical industry and agro-industrial waste treatments Kot et al. [21]. Yeast strains such as Sporobolomyces ruberrimus have been found as first time in vineyards Castrillo et al. [13]. The study and preservation of this regional yeast reservoir is important since it can harbour new strains with potential application not only in oenology but also in other industrial applications beyond the oenological domain [22,23].

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