

ORGANIC AND BIODYNAMIC VITICULTURE: A SYSTEMATIC REVIEW AND META-ANALYSIS

VITICULTURE BIO ET BIODYNAMIQUE: UNE REVUE SYSTÉMATIQUE ET UNE MÉTA-ANALYSE

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Abstract

In agriculture including viticulture demand for organically grown crops has developed exponentially in the last few decades. Particularly in the wine sector organic and biodynamic management system are gaining more and more importance and some of the most prestigious wineries have converted to organic or biodynamic viticulture. The main objective of this study was to summarize the outcome of scientific trials done on organic and biodynamic viticulture worldwide and to thereby precisely describe and quantify the effects of the respective management systems. The review addresses the question if and how conventionally, organically and biodynamically-managed vineyards differ concerning vine growth and yield, grape composition and wine sensory characteristics. There is a qualitative statement showing overall effects of organic and biodynamic management in viticulture and quantitative findings through regression analyses of available datasets, which describe the magnitude of the effect of organic or biodynamic viticulture on different parameters. Organic and biodynamic management practices in viticulture strongly affect vine and wine properties such as yield, growth and wine sensory characteristics, but have minor effects on juice sugar concentration. This work provides a comprehensive view on organic and biodynamic viticulture and their effects on production.

Keywords: organic viticulture, biodynamic viticulture, vine, wine, wine sensory characteristics

Résumé

Dans l'agriculture aussi bien que dans la viticulture la production et la demande de produits biologiques ont été développées de façon exponentielle au cours des dernières décennies. Particulièrement dans le secteur du vin, le système de gestion biologique et biodynamique devient de plus en plus important et certains des domaines les plus prestigieux ont adopté ces systèmes de gestion. L'objectif principal de cette étude est de résumer les résultats des essais scientifiques effectués sur la viticulture biologique et biodynamique dans le monde entier et de décrire et quantifier précisément les effets des systèmes de gestion respectifs. La revue pose la question si et comment les vignobles conventionnels, biologiques et biodynamiques diffèrent en ce qui concerne la croissance et le rendement de la vigne, la composition des raisins et les caractéristiques sensorielles du vin. Il existe une approche qualitatif montrant les effets globaux de la gestion biologique et biodynamique dans la viticulture et une approche quantitatif grâce à des analyses de régression des ensembles de données disponibles, qui décrivent l'ampleur de l'effet de la viticulture biologique ou biodynamique sur différents paramètres. Les pratiques de gestion biologique et biodynamique de la viticulture influent fortement sur les propriétés de la vigne et du vin telles que le rendement, la croissance et les caractéristiques sensorielles du vin, mais ont des effets mineurs sur la concentration de sucre dans le mû. Ce travail offre une vision complète et profonde de la viticulture biologique et biodynamique et ses effets.

Mots clés: viticulture bio, viticulture biodynamique, vigne, vin, caractéristiques sensorielles du vin

Introduction

Since the beginning of the 20th century, organic agriculture has dramatically gained in importance and influence worldwide. In agriculture including viticulture the demand for organically grown crops has developed exponentially in the last few decades. Beyond that more and more political attempts have been made to limit the use of synthetic pesticides and thus to promote organic farming. The start of organic agriculture that developed almost independently in the German- and English-speaking world dates back to the beginning of the last century. The Life Reform movement, the Food Reform movement as well as biodynamic agriculture founded by Rudolf Steiner were the first movements towards organic agriculture (Steiner, 2005; Vogt, 2000).

Today organic and biodynamic viticulture is restricted by legislative regulations worldwide. The legislative framework for organic and biodynamic viticulture in the EU, US and Australia is described in Regulation (EC) No 834/07 and No 889/08, in Regulations of the National Organic Program by the US Department of Agriculture (USDA) and in the National Standard for Organic and Bio-Dynamic Produce set by the Biosecurity section of the Department of Agriculture (Australia), respectively.

The aim of this study is to summarize the outcome of scientific trials assessing organic and biodynamic viticulture worldwide and hence characterizing the effects of the respective management systems. The review addresses the question of whether conventionally, organically and biodynamically managed vineyards differ in regards to vine growth and yield, grape composition, wine quality and production costs. There is a qualitative statement showing overall effects of organic and biodynamic viticulture and quantitative statements through regression analyses of available datasets, which describe the magnitude of the effect of organic or biodynamic viticulture on vine growth, yield and juice sugar concentration. By describing and quantifying the effects of the respective viticultural management systems the review provides decision support for producers, consumers as well as researchers. In addition, new findings concerning the reasons for the effects of organic and biodynamic management in viticulture are described. Different hypotheses for explaining the observed phenomena are presented.

Materials and methods

Literature searches of peer-reviewed published literature were conducted to find studies investigating organic and/or biodynamic viticulture. Only field trials that used replicates of management treatments with representative plots or studies that used a representative number of samples were included in the review.

Data from non-peer-reviewed sources such as conference proceedings, master theses or doctoral dissertations were also included into this study if they met the criteria mentioned above. Furthermore, unpublished data from two long-term trials in Germany and in Australia were provided by the authors and were included into the review and into the meta-analysis.

Linear regression analyses were performed in order to evaluate the quality of the correlations of several parameters (growth, yield and total soluble solids in juice) between conventionally and organically and between organically and biodynamically managed vineyards, respectively. To assess if conventional and organic or organic and biodynamic viticulture differ significantly in vine growth, vine yield and total soluble solids in juice and if the observed effects were consistent across all environments ANOVA and Tukey-Test were performed.

Results and Discussion

A reduction in vigor, expressed as pruning weight, shoot length, canopy density or LAI, respectively, of organically managed vineyards compared to conventional management was observed for several varieties under differing climatic conditions (Hofmann, 1991; Corvers, 1994; Kauer, 1994; Malusà et al., 2004; Meißner, 2015; Pike, 2014; Collins et al., 2015(1); Döring et al., 2015). When pruning weight of organic or biodynamic and conventional management was compared by regression analysis taking into consideration all available datasets of scientific trials, organic and biodynamic treatments showed 19 % less growth as pruning weight compared to conventional treatments. In organic plots microbial biomass C and C_{mic}/C_{org} were generally higher (Freitas et al., 2011; Gehlen, 1988; Okur et al., 2009; Probst et al., 2008) and no consistent differences in soil N, P, S could be observed in several field trials (Collins et al., 2015(1); Probst et al., 2008; Wheeler, 2006). Therefore these parameters cannot account for the observed differences in growth. It seems more likely that the observed reduction in physiological performance in organic plots reported by Döring et al. (2015) might account for the growth differences between conventional and organic or biodynamic management. It could be hypothesized that the cover crop mixture rich in legumes used in organic and biodynamic viticulture to enhance biodiversity and to ensure nitrogen supply have an impact on water availability in the soil and thus interact with the root system of the vines. When soil moisture was assessed in the long-term field trial in Australia during the growing season 2010/2011, a significant decrease of soil moisture content under organic management at 20 cm up to 1 m depth was observed compared to the high input conventional system during the whole growing season (Collins et al., 2015(1)). It is likely that differences in the root system of the vines or the water availability in the soil due to cover cropping might account for different levels of plant growth regulators such as gibberellic acid, cytokinin and auxin that strongly determine growth and vigor. Root exudates of the different cover crop species might also interact with the vine roots and might thereby influence vine growth and vigor.

Most of the authors report a yield loss in organic viticulture compared to conventional production from 10% up to 30% for several varieties (Danner, 1985; Hofmann, 1991; Corvers, 1994; Kauer, 1994; Pool and Robinson, 1995; Malusà et al., 2004; Wheeler, 2006; Meißner, 2015; Collins et al., 2015(2); Döring et al. 2015). Regression analysis shows that organic and biodynamic treatments have 15 % less yield compared to conventional treatments. Cluster and berry weights decreased under organic viticulture in several trials on different varieties (Linder et al., 2006; Pool and Robinson, 1995; Meißner, 2015; Collins et al., 2015(1); Döring et al., 2015). Since reproductive development of *Vitis vinifera* is highly sensitive to the water status the lower water availability in the organic and the biodynamic management system might account for differences in physiological performance and might cause yield differences. Lower water availability early in the season was shown to cause decreases in yield and cluster weight (Matthews and Anderson, 1989). Since the period from initiation to maturation of winegrapes comprises two growing seasons, early season water deficit might have implications for cluster weight of the current year and the number of clusters of the subsequent year (Döring et al., 2015; Matthews and Anderson, 1989).

Results concerning the impact of organic viticulture on grape quality parameters, juice and wine quality are inconsistent. In a lot of trials no differences in grape composition of several researched grape varieties were observed (Danner, 1985; Hofmann, 1991; Kauer, 1994; Henick-Kling, 1995; Malusà et al., 2004; Linder et al., 2006; Wheeler, 2006; Tassoni et al., 2013; Tassoni et al., 2014; Collins et al., 2015(1); Collins et al., 2015(2); Döring et al., 2015). Regression analysis showed that the juice sugar concentration of organically and biodynamically managed vineyards was 1 % higher compared to that of conventionally managed vineyards. One very important parameter determining potential level of total soluble solids in grape juice is the leaf-area-to-fruit-weight-ratio (Kliewer and Dokoozlian, 2005). Döring et al. (2015) measured this ratio under integrated, organic and biodynamic management. The organic and the biodynamic treatments showed slightly higher levels of leaf-area-to-fruit-weight-ratio, but there was no significant difference among treatments. One reason why organically and biodynamically managed vineyards do not differ significantly from conventional vineyards in total soluble solids in juice could be the simultaneous decrease of growth and yield. Results by Collins et al. (2015(1)) concerning the ratio of yield:pruning weight support that there is no difference among the systems concerning the ratio of vegetative and reproductive growth. Another reason for the fact that systems did not differ in the amount of total soluble solids at harvest might be that physiological performance after veraison that highly determines final sugar content and berry quality traits, did not differ significantly among treatments when measured in the long-term field trial in Germany (Döring et al., 2015; Hardie and Considine, 1976).

Results concerning the sensory characteristics of wines derived from organic and conventional management are inconclusive. No influence on wine sensory characteristics could be observed (Danner, 1985; Henick-Kling, 1995; Kauer, 1994; Meißner, 2015; Dupin et al., 2000). However, in two of these studies the wines from conventional management were perceived as more floral, fruity, vegetal and complex (Dupin et al., 2000; Meißner, 2015), whereas the wines from biodynamic management tended to be more balanced, full-bodied, with a stronger minerality and more length (Meißner, 2015). Wines from the Australian long-term-trial on Cabernet Sauvignon were characterized by quantitative descriptive analysis and wines from biodynamic plots were assessed as more rich, textual, complex and vibrant in comparison to wines from conventionally managed plots (Collins et al., 2015(2)).

The comparison of biodynamic and organic viticulture showed similar characteristics (Collins et al., 2015(1); Danner, 1985; Döring et al., 2015; Granato et al., 2015(1); Granato et al., 2015(2); Laghi et al., 2014; Meißner, 2015; Parpinello et al., 2015; Partignani et al., 2017; Picone et al., 2016; Reeve et al., 2005; Tassoni et al., 2013; Tassoni et al., 2014). Two recent studies on organic and biodynamic viticulture observed significantly lower pre-dawn water potentials in the biodynamic plots, one done on *Vitis vinifera* L. cv. Riesling in Germany (Döring et al., 2015) and one done on *Vitis vinifera* L. cv. Sangiovese in Italy (Botelho et al., 2015). One of the two studies observed stomatal conductance of the biodynamic plots to be lower (Botelho et al., 2015). At the same time a significant increase in leaf enzymatic activity of the biodynamic plots for *Vitis vinifera* L. cv. Sangiovese was observed (Botelho et al., 2015). The enzymatic activities that were found to increase under biodynamic management are linked to biotic and abiotic stress and are associated to induced resistance against several fungi. One hypothesis is that especially the horn silica preparation 501 made from quartz powder might upregulate plant defense mechanisms attributed to induced plant resistance (Botelho et al., 2015). This again might have implications for berry composition under biodynamic management (Laghi et al., 2014; Parpinello et al., 2015; Picone et al., 2016; Reeve et al., 2005).

No differences in sensory characteristics of the wines could be detected concerning *Vitis vinifera* L. cv. Grüner Veltliner and Sangiovese (Danner, 1985; Parpinello et al., 2015; Partignani et al., 2017). By contrast Meißner (2015) reports a sensorial preference of *Vitis vinifera* L. cv. Riesling wines from biodynamic management in comparison to the ones from the organic plots. Ross et al. (2009) could detect significant differences between *Vitis vinifera* L. cv. Merlot wines from organic and biodynamic plots of a field trial in two out of four years, but sensory characteristics attributed to the different wines were not consistent over the years.

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