INTEGRATION OF VERMICOMPOSTING OF WINE BY-PRODUCTS IN VINEYARDS FOR REGENERATIVE VITICULTURE

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Abstract

The gap between high agricultural yields and ecosystem sustainability cannot be closed without significant changes in ecosystem processes. Green revolution methods focus on external interventions, whereas internal ecosystem management has considerable potential to improve yields with less environmental impact. Vineyards are often managed intensively to maximize wine production, leading to reduced biodiversity, soil fertility, and environmental problems. This study provides an overview of how earthworms and vermicomposting can support the circular economy and sustainable agriculture by creating an integrated cycle that converts by-products from the local wine industry into vermicompost that can be used as a biofertilizer and soil enhancer in vineyards. The results of a long-term study are presented, in which grape marc from white and red wine production was processed in pilot-scale vermireactors, and the resulting vermicompost was applied to the vines in the same vineyards where the grapes were harvested, in various solid and liquid formulations. The effects on vineyard soils and vines were monitored over several growing seasons in two biogeoclimatic zones with distinct grape origins. Wine produced from grapes fertilized with vermicompost derived from grape pomace was compared with standard wine from the wineries. The results of this research have important implications for guiding the wine industry toward a circular economy and sustainable, regenerative viticulture.

Introduction

Grapes are the most important fruit crop in the world, with more than 7 million hectares harvested and annual production of around 80 million tons. Approximately 50% of global production is used for wine, and around a third of this volume ends up as waste, with grape marc as the main by-product (OIV, 2023). Grape bagasse, pomace, or marc consists of the skin, pulp, and seeds that remain after the grapes are pressed to obtain the must. It is a valuable resource for producing ethanol, grape seed oil, bioactive compounds, and animal feed. It can also be used as a nutrient-rich organic soil amendment. However, when applied directly without prior treatment, it can harm crops because of its acidity and high levels of phytotoxic polyphenols. At the same time, vineyards are often managed intensively to maximize production, leading to reduced soil biodiversity, decreased soil fertility, and various environmental impacts (Tilman *et al*., 2002; Visconti *et al*., 2024). However, sustainable production systems tend to yield less than intensive systems, making optimization necessary. The gap between high agricultural yields and ecosystem sustainability can be closed only through substantial modifications to ecosystem processes. Vermicomposting is a biodegradation process in which certain detritivorous earthworm species interact intensively with microorganisms, thereby drastically affecting decomposition, accelerating the stabilization of organic matter, and substantially modifying its physical, chemical, and biological properties (Domínguez *et al*., 2004, 2010). Vermicompost, the end product of vermicomposting, is a biologically stable, very fine, porous material with high water retention capacity, a low C/N ratio, and high nutrient content. It also contains complex microbial communities that confer a wide range of beneficial effects on the soil-plant system (Domínguez *et al*., 2019). Vermicompost and its liquid derivatives have been shown to increase the growth and productivity of many crops. Many experimental studies have demonstrated that vermicompost increases the growth and productivity of many horticultural crops (Lazcano *et al*., 2009). These effects occur independently of the nutrients provided and may be due to biological mechanisms associated with microbial activity (Domínguez *et al*., 2019). Based on these premises, in 2012 we began the current 'EWINE' project, which studies the combined and synergistic activity of worms and microorganisms during vermicomposting to develop an integrated cycle that converts the by-products generated by the wine industry in vineyards and wineries into vermicompost, an excellent product that is applied to vineyards as a biostimulant for soil and plants.

MATERIALS AND METHODS

Vermicompost production

Vermicomposting was applied and studied on a pilot scale using residual by-products generated in the wine industry, with the aim of producing high-quality vermicompost that meets the requirements of the legislation regulating fertilizer production. The biofertilizer and biopesticide effects of vermicompost were studied in vineyards in two geographical areas and two designations of origin. Raw and distilled grape marc from white wine varieties (*Vitis vinifera* var. Albariño) and red wine varieties (*Vitis vinifera* var. Mencía) were processed in pilot-scale vermireactors. *Eisenia andrei* earthworms were used for vermicomposting. The process produced a high-quality organic fertilizer free of

polyphenols and grape seeds. The density and structure of the worm population, as well as worm biomass, were monitored or determined monthly.

Vermicompost parameters and application on vineyards

The effects of earthworms on grape marc during vermicomposting have been studied, focusing on changes in microbial communities, including abundance, composition, structure, diversity, and activity. Vermicompost obtained from different wine varieties was applied in solid and liquid forms to vineyards in Rías Baixas (Albariño) and Ribeira Sacra (Mencía) over eight years (2014–2022). Field experiments involved 240 vines with control, solid, and liquid treatments, while foliar spray applications were tested on 69 vines, including controls and conventional phytosanitary treatments, with treatments applied every 15 days and mildew infection monitored. Wines were produced from grapes fertilized with grape marc-derived vermicompost in commercial vineyards, following standard winemaking procedures, alongside control wines from untreated vines, thereby allowing assessment of the effects of vermicompost on vineyard soil, vine development, and final wine production.

RESULTS AND DISCUSSION

Vermicomposting of grape marc or bagasse

Vermicomposting reduced the biomass of grape marc by 50–70%, and the process produced a nutrient-rich (**Table 1**), microbiologically active, and stabilized material, like peat, that is easily separated from the seeds by sieving.

Table 1. Physical-chemical characterisation of the vermicompost used.

Comp.	Conc. ($g \cdot kg^{-1}_{DW}$)	Des. (±)	Comp.	Conc. ($g \cdot kg^{-1}_{DW}$)	Des. (±)	Comp.	Conc. ($g \cdot kg^{-1}_{DW}$)	Des. (±)
Organic Matter	750	3.4	Magnesium	3.82	0.04	Lignin	323	2.4
Carbon	376	1.47	Sulphur	6.06	0.05	Cellulose	58	10.4
Nitrogen	29.6	0.13	Iron	8.0	0.28	Hemicell.	30.6	0.54
Phosphorus	8.4	0.32	Manganese	1.75	0.01	Tot. Polyph.	12.5	0.70
Potassium	11.4	0.65	Boron	0.0054	0.00011			
Calcium	22.5	0.66	Molybdenum	0.0248	0.00023			
Calcium	22.5	0.66	Molybdenum	0.0248	0.00023			

Comp. (Component) · Conc. (Concentration) · Des. (Deviation) · Hemicell. (Hemicellulose) · Tot. Polyph. (Total Polyphenols)

Effects of applying grape marc vermicompost in vineyards

Fertilization with vermicompost significantly increased grape production, as evidenced in the case study (Figure 2) for both liquid and solid vermicompost applications. This pattern was observed across both designations of origin and both biogeoclimatic zones. We have collected data from nine vintages or harvests between 2014 and 2022, and although the results vary by year, region, grape variety, and plant age, in all cases the vines treated with vermicompost produced significantly more grapes than the vines not treated with vermicompost.

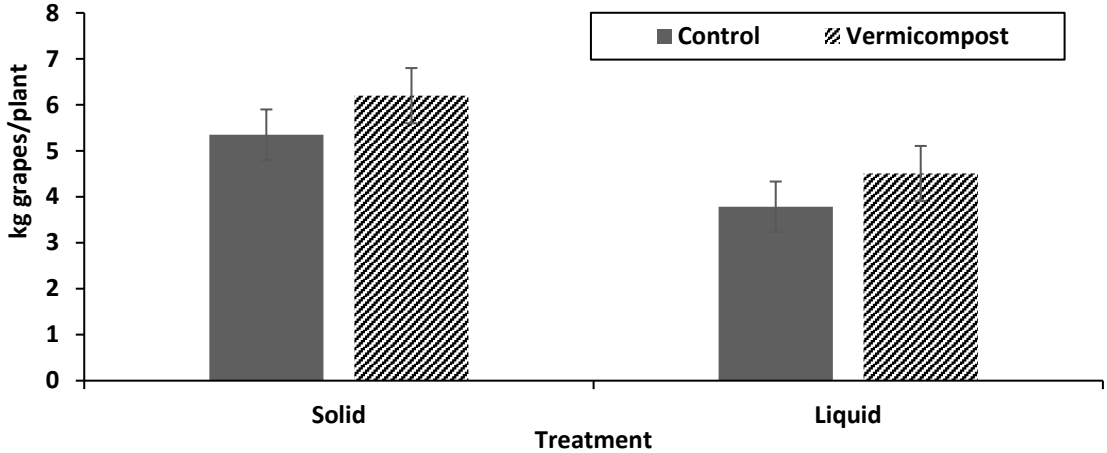

Figure 2. Case study of the effect of applying solid and liquid vermicompost on grape production.

A visual analysis of multiple grapevine strains across different harvests revealed that foliar sprays made from solid vermicompost acted as biopesticides, providing protection. During the grape growth stages in the vineyards, untreated vines showed more severe mildew symptoms (see Figure 3), whereas foliar spray application reduced these symptoms to a level comparable to that achieved with conventional pesticides.

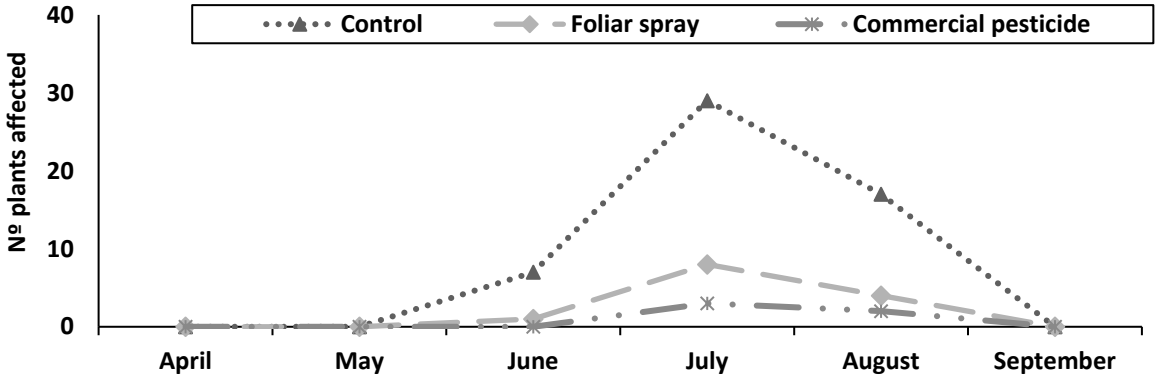

Figure 3. Effect of applying different phytosanitary treatments on the number of plants affected by mildew during the growing season in grapevine strains.

Blind tastings at the two wineries revealed notable differences in the organoleptic properties of wines made from grapes grown on treated vines, including greater complexity, expression, freshness, and overall balance, as well as better visual intensity and flavor persistence. These wines received higher ratings and reviews. This research has led to significant advances in the application of vermicomposting technologies in the wine sector. The two wineries where the experiments were conducted have constructed vermicomposting reactors and now process all their marc using this method, applying the resulting vermicompost to their vineyards.

CONCLUSIONS

Vermicomposting is a circular economy solution for the use of by-products from agriculture and the food industry. It improves the sustainability of processes and agroecosystems, as well as soil and plant health. The end product, vermicompost or worm humus, contains a variety of microorganisms and nutrients that plants can more easily absorb. In vineyards where it was incorporated, the nutrient-rich vermicompost increased production capacity, minimizing the need for commercial synthetic fertilizers. This technique has been successfully applied within the framework of a circular economy in the wine sector. Commercial vineyards produce an industrial by-product called grape marc, which consists of the skins, pulp and seeds of grapes after they have been processed for wine production. While grape marc is already used as an organic soil amendment, its high acidity and phytotoxic polyphenol content render it unsuitable as a fertilizer without prior processing. Vermicomposting grape marc provides an economical solution for processing this abundant by-product. Fertilization with vermicompost significantly improved both grape production and grape and wine quality.

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REFERENCES

Domínguez, J. *et al*. 2004. In: CA Edwards. Earthworm Ecology (2nd edition) CRC Press LLC, pp 401-424
Domínguez, J. *et al*. 2010. In: Heribert Insam. Microbes at work: from wastes to resources Springer, pp 93-114
Domínguez, J. *et al*. 2019. Scientific Reports 9, 9657
Lazcano, C. *et al*. 2009. In: M. Miransari. Soil Nutrients Nova Science Publishers, New York, pp 230-254
International Organisation of Vine and Wine (OIV) 2023. Available at: oiv.int
Tilman, D. *et al*. 2002. Nature 418, 671–677
Visconti, F. *et al*. 2024. Horticulturae 10, 154