Life Cycle Assessment of grape production. Potential environmental benefits of an alternative solution for fungal diseases control

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Abstract In the project Grape4Vine an innovative solution was developed. In detail, the Grape4vine project aims at exploiting winegrowing byproducts that would be normally treated as wastes, to produce biotechnological means for controlling downy mildew and powdery mildew in the circular economy context. In detail, the Grape4Wine solution is based on dsRNA (double-stranded RNA) able to induce RNA interference (RNAi) and silencing pathogen or plant genes necessary for infection and thus avoid the onset of plant disease. However, to assess the sustainability of the proposed solution, the first step is to quantify the impact of fungal disease control during grape cultivation. In this context, the aim of this study is to evaluate the environmental impact of grape cultivation by paying particular attention to pest and disease control. To this purpose, the Life Cycle Assessment approach was applied to data collected in different viticulture farms located in northern Italy.

Keywords: Life Cycle Assessment, Precision viticulture, Pesticide Application, Sustainability

1. Introduction

Viticulture is one of the most important sectors of Italian agriculture, not only for its economic relevance but also for its role in landscape definition and soil management. Among the different challenges of viticulture, pest and disease control is by far the most important. In particular, the control of fungal diseases is a key aspect about downy mildew and powdery mildew. The application of pesticide is usually the most applied solution even if this practice is responsible for a considerable environmental impact Over the years different solutions have been tested for the control of fungal diseases. In the project Grape4Vine an innovative solution was developed. In detail, the Grape4vine project aims at exploiting winegrowing byproducts that would be normally treated as wastes, to produce biotechnological means for controlling downy mildew and powdery mildew in the circular economy context. In detail, the Grape4Wine solution is based on dsRNA (double-stranded RNA) able to induce RNA interference (RNAi) and silencing pathogen or plant genes necessary for infection and thus avoid the onset of plant disease. However, to assess the sustainability of the proposed solution, the first step is to quantify the impact of fungal disease control during grape cultivation. In this context, the aim of this study is to evaluate the environmental impact of grape cultivation paying particular attention to pest and disease control. To this purpose, the Life Cycle Assessment approach was applied to data collected in different viticulture farms located in northern Italy.

2. Materials and methods

The environmental impact was evaluated using the Life Cycle Assessment (LCA) approach. LCA was developed for industrial processes but it is always more and more applied also to agricultural systems. LCA converts the material and energy flows between the evaluated production system and the atmosphere in a list of numerical environmental indicators such as carbon footprint, water footprint (ISO, 2006).

2.1. Functional unit, system boundaries

1 ton of harvested grape was selected as functional unit and, regarding the system boundary, a “from cradle to farm gate” perspective was considered. All the operations of the wine supply chain until the harvesting of grape were included in the system boundary where the ones after this operation were excluded. More in detail, the extraction of the raw materials used to produce all the production factors (fuel, pesticides, fertilizers) as well as all the field operations except planting were included in the system boundary while the winemaking as well as the operation of bottling, distribution and use were excluded.

2.2. Inventory data collection

Primary data regarding productive performances, the cultivation practice as well as the consumption of fuel, fertilizers and pesticides were collected by means of surveys and visits to different farms. The farms are located in norther Italy and applied both conventional than organic farming. The main primary data collected during the surveys and the interviews with the farmers refer to the cultivation practices and, in particular, to the mechanization of the field operations (characteristics of the operative machine and tractors, amount of fuel consumed, working time), amount of fertilizers and pesticide applied, productivity and management of the pruning residues. Secondary data were considered about the emissions related to fuel combustion and fertilizers and pesticides applications. In detail, with regard to the emissions of the pesticide active ingredients the guidelines PEFCR (European Commission, 2018) were applied. Consequently, 90% of the active ingredients were emitted to agricultural soil, 9% to air, 1% to water.

2.3. Impact assessment

The characterization of inventory data to potential environmental impacts was carried out using the characterized factors provided by the Environmental Footprint 3.1 (adapted) V1.00 / EF 3.1 normalization and weighting set method (Bassi et al., 2023). The following impact categories were analyzed: Acidification (A, expressed as mol H+ eq.); Climate change (CC, expressed as mass of CO2 eq.); Ecotoxicity, freshwater (FEx expressed as CTUe); Particulate matter (PM expressed as disease inc.); Eutrophication, marine (ME expressed as mass of N eq.); Eutrophication, freshwater (FE expressed as mass of P eq.); Eutrophication, terrestrial (TE expressed as mol N eq.); Ozone depletion (OD, expressed as mass of CFC-11 eq.); Human toxicity, non-cancer (HT - noc, expressed as CTUh); Human toxicity, cancer (HT - c, expressed as CTUh); Photochemical ozone formation (POF, expressed as mass of NMVOC eq.); Resource use, fossils (FRU, expressed as MJ); Resource use, minerals and metals (MMRU, expressed as mass of Sb eq.); Water use (WU, expressed as m3 depriv.).

3. Results

The results show how yield is the main driver for all the environmental impacts while, about the different inputs, fuel and fertilizers play a major role. The application of pesticides is the field operation with the higher contribution to the total impact in particular when fertilization is not carried out. These applications affect the environmental impact mainly due to the mechanization of the field operation, the consumption of pesticides (whose manufacturing is energy-intensive), and the emissions of active ingredients into air, water, and soil. The mechanization of pesticide application involves significant environmental impacts largely due to diesel consumption and the related emissions from tractor engines. Pesticide production encompasses various processes, including extraction and processing of raw materials, chemical synthesis, packaging, and transportation. These energy-intensive stages contribute significantly to global warming potential, ozone depletion and resource depletion. The share of impact related to pesticide applications is quite variable (from 1-3% to 75-95%) among the different impact categories. Toxicity related impact categories are deeply affected by the emissions of the pesticide active ingredients into the environment.
In this regard, it is evident how the adoption of strategies based on the dsRNA developed during Grape4Vine could result in considerable impact reduction in some impacts (the toxicity related categories) and in less relevant benefits for all the other environmental effects.

4. Conclusion

Even if the environmental impact of grape production is strictly related to the yield, the research outcomes underlined how the role of pesticide applications cannot be neglected. In this context, the benefits related to the adoption of alternative solutions for the control of fungal diseases are interesting not only from an environmental point of view but also from an economic and social perspective.

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References

Andreasi Bassi, S., Biganzoli, F., Ferrara, N., Amadei, A., Valente, A., Sala, S., & Ardente, F. (2023). Updated characterisation and normalisation factors for the Environmental Footprint 3.1 method. Publications Office of the European Union: Luxembourg.

ISO, 2006a. ISO 14040:2006: Environmental management – Life cycle assessment – Principles and framework. International Organization for Standardization, Geneva.

ISO, 2006b. ISO 14044:2006: Environmental management — Life cycle assessment — Requirements and guidelines. International Organization for Standardization, Geneva.

European Commission-Single Market for Green Products. Product environmental footprint category rules (PEFCR) for still and sparkling wine. Published 26/04/2018.