EXTENDED ABSTRACT

Under-vine cover crops in viticulture: impact of different weed management practices on weed suppression, yield and quality of grapevine cultivar Riesling

Katharina Weihbrecht[1], Heinrich Scherer[2], Ralf Pude[3], Stefan Pätzold[4], Claudia Huth[1], Jochen Bogs[5]
*Corresponding author: katharina.weihbrecht@dlr.rlp.de

[1] Institute of Viticulture and Oenology, State Education and Research Center of Viticulture, Horticulture and Rural Development (DLR Rheinpfalz), Neustadt an der Weinstraße, Germany
[2] Institute of Crop Science and Resource Conservation (INRES), Plant Nutrition, University of Bonn, Bonn, Germany.
[3] Institute of Crop Science and Resource Conservation (INRES), Renewable Resources, University of Bonn, Campus Klein-Altendorf, Rheinbach, Germany.
[4] Institute of Crop Science and Resource Conservation (INRES), Soil Science and Soil Ecology, University of Bonn, Bonn, Germany.
[5] Weincampus Neustadt, State Education and Research Center of Viticulture, Horticulture and Rural Development (DLR Rheinpfalz), Neustadt an der Weinstraße, Germany.

Keywords: cover crops, weed suppression, grapevine, under-vine, herbicide, mechanical tillage

INTRODUCTION

The regulation of weeds, particularly in the under-vine area of grapevines, is essential for the maintenance of grape yield and quality. This is achieved primarily through herbicide application or mechanical tillage. However, the use of herbicides is controversial due to potential environmental and human health impacts (VAN BRUGGEN et al. 2021). Mechanical tillage represents an alternative that can be employed in organic vineyards. This method also presents certain disadvantages, especially in regard to soil erosion potential, the risk of damage to the vines, inconsistent efficiency and the associated costs for energy, machinery and labour. Given these challenges, alternative, sustainable approaches to weed management are essential for modern viticulture.

The implementation of cover crops in the under-vine zone has been demonstrated to be an effective method for weed regulation, which simultaneously results in improvements in soil structure and soil temperature (ABAD et al. 2023). However, the impact of this approach on soil moisture levels remains relatively unclear (BAVOUGIAN & READ 2018). In terms of grape vine performance, a reduction in growth and yield has been evidenced (CHOU et al. 2018; CONIBERTI et al. 2018), as well as an increase in root length density at deeper soil layers (FLEISHMAN et al. 2023). A reduction in vigor and deeper roots of grapevine, as well as the impact on soil health, could lead to greater resilience in viticulture.

In order to benefit from the positive aspects of under-vine cover crops, it is essential to select appropriate plant species and establish them effectively. This research project was therefore initiated to address the limited number of studies on under-vine cover crops in European viticulture in non-irrigated vineyards with cool climate conditions. Furthermore, there is a need to explore the impact of different plant species, beyond the potential cost savings offered by perennial cover crops, which also possess ecological advantages.

RESEARCH OBJECTIVES

The purpose of this study is to evaluate sustainable weed management strategies in viticulture, focusing on the use of under-vine cover crops as an alternative to traditional methods such as mechanical tillage and herbicide application. The study aims to assess the impact of these cover crops on weed suppression, soil moisture, soil temperature, grape quality and yield in a non-irrigated, 7-year-old Riesling vineyard located in a cool-climate region. Conducted over a three-year period from 2022 to 2024, this research seeks to address the challenges posed by climate change, such as prolonged dry periods and heavy rainfall events, by exploring the potential of cover crops as a climatic buffer. Additionally, the study investigates the potential for long-term cost savings through sustainable, multi-year under-vine greening strategies, contributing to more resilient and eco-friendly viticulture practices.

MATERIAL AND METHODS

Description of experimental sites and variants

The study was conducted from 2022 to 2024 in a non-irrigated vineyard planted in 2014 with the Riesling clone N90 on the rootstock SO2. The vineyard is located in Neustadt/Weinstraße in the Pfalz region of Germany, which is characterised by a relatively cool climate. The average temperature over the past five years was 12.14°C, with an

annual mean precipitation of 491.9 mm. The soil of the vineyard has been analysed and classified as sandy loam (VDLUFA-Bd I D 2.1:1997 \ 71).

For the purposes of this study five variants of under-vine cover crops were used: Festuca rubra (red fescue), Medicago lupulina (black medic), Thymus serpyllum (wild thyme), herb mixture and clover mixture. Natural vegetation and two standard practices, mechanical tillage and herbicide application, were used as comparison methods.

The experiment was designed as a randomised block design with four replications, with each plot measuring 15 metres long by 0.5 metres wide and consisting of 15 vines in a row. In September 2021, all plots were prepared using a disc plough, hand hoeing and raking.

Site-specific weather conditions

Air temperature and air moisture were recorded at 15-minute intervals using HOBO® weather sensors and data loggers positioned within the leaf zone of the experimental vineyard. Additionally, a nearby weather station measured rainfall and air temperature.

Vegetation cover ratio (VCR) and weed suppression

In order to estimate the cover ratios, four measurement points (0.4 m wide and 1 m long) between two vines were used for each plot. Using the Londo scale (LONDO 1976), the proportion of bare ground, dead plant parts (litter) and

After soil preparation, cover crops were sown by hand at rates based on the supplier's recommendations with an additional 20 %. In the natural vegetation variant, no action was taken during the experimental period. Mechanical tillage was carried out 4-5 times per year with a disc plough. Herbicides were applied twice a year: the first application was with glyphosate and flazasulfuron, the second with glyphosate only. In the first year of the study (2022) no herbicides were applied, so data collection for this variant was limited to 2023 and 2024. As the cover crops black medic and clover mixture could not be implemented for more than 2 years, data for these variants are not shown.

individual weed species, as well as sown plants, was assigned to one of 13 rating classes. The mean values of the classes were used to calculate the average cover. Weed suppression efficiencies are calculated according to (ABBOTT 1925).

Soil moisture and temperature

TOMST® TMS dataloggers were used to measure soil moisture at -40 and -6 cm and temperature at -40, -6, +2 and +15 cm depth. With the time-domain transmission method raw soil moisture values are recorded and converted to volumetric soil moisture using the calibration function in the supplied Lolly software.

Infiltration rate

The infiltration rate of water into the soil was measured using the double ring infiltrometer (DRI) test with an inner ring of 0.18 cm diameter and an outer ring of 0.28 cm diameter.

Grape quality and quantity

For the bending degree of rachis (°), an indirect estimation of bunch compactness, 100 grapes were classified into five classes according to IPACH et al. (2005). The bunch rot incidence and severity of Botrytis cinerea infection on grapes was determined using a seven-class scheme on 100 grapes based on EPPO guideline PP 1/17(3) Botrytis cinerea on grapevine. A sample of 100 berries was used for berry weight determination and must analysis. The berries were processed using a bag mixer, fruit press and centrifuge. The must obtained was analysed by FTIR-WineScan™ (Foss, 3400 Hilleroed, Denmark), the must density (sugar content), total acidity and NOPA (yeast-usable nitrogen content) were determined. To measure the yield per vine, grapes from six vines were harvested and weighed. Statistical analysis

Statistical analyses were performed in R (version 4.x, R Core Team, 2024). One-way ANOVA followed by Tukey's HSD test and regression models were used.

RESULTS

Vegetation cover ratio (VCR) and weed suppression

The VCR of the cover crops varied considerably and was influenced by the year. Black medic and the clover mixture were not able to establish and suppress weeds for 2 years or more. Red fescue and herb mixture showed good establishment in the first, second and third year. Wild Thyme was slower growing and took 2 years to establish well.

In 2024, three years after sowing, the VCR of sown plants was 91.4 % for red fescue, 68.6 % for wild thyme and 72.5 % for the herb mixture. These values correlate with their weed suppression efficacy, which was comparable to that of the herbicide. At this point, mechanical tillage showed a significantly higher VCR of weeds, which was comparable to that of the natural vegetation variant. Weed suppression by the herbicide remained stable throughout the measurement period, which was not the case for all cover crops.

Soil moisture and temperature

Cover crops showed different effects on soil moisture and temperature depending on crop type and climatic conditions. During the heat period in 2023, a significantly cooler soil surface temperature was recorded for red fescue and herb mixture compared to mechanical tillage herbicide. Soil moisture in 6 cm depth was significantly lower shortly after mechanical tillage compared to all other treatments. Infiltration rate

In 2024 herbicides had a significantly lower water infiltration rate than natural vegetation, red fescue and wild thyme.

Grape quality and quantity

Bunch compactness was significantly influenced by the treatments: All cover crops and natural vegetation had lower bunch compactness than those of mechanical tillage and herbicides in 2023. In 2024, bunch compactness of cover crops was significantly lower than that of herbicides.

The incidence of Botrytis bunch rot in the mechanical treatment was significantly higher in 2022 compared to that in the red fescue treatment. In 2024, the herbicide treatment showed significantly higher values for bunch rot incidence compared to natural vegetation, wild thyme and red fescue. Also in 2024, bunch rot severity was significantly higher in the chemical treatment compared to natural vegetation and all cover crop treatments.

In 2024, the herbicide treatment showed significantly higher values for yield compared to wild thyme. Must analysis and berry weight were not significantly affected by the treatments.

CONCLUSION

Under-vine cover crops such as red fescue, wild thyme, and herb mixture have shown good results in controlling weed growth compared to herbicide application and mechanical tillage. By covering the soil, they help retain soil moisture, regulate temperature, and act as a climate buffer. However, their effectiveness varied over time and was influenced by climatic conditions. Under-vine cover crop variants had an effect on yield or grape quality within three years after establishment. Interestingly, positive effects were observed on grape bunch structure and health, particularly in reducing Botrytis bunch rot incidence. However, in the third year, the presence of cover crops was associated with a reduction in yield. The results of this study suggest that cover crops could serve as a viable alternative to mechanical tillage or herbicide use in cool climates without irrigation. Nevertheless, further research is needed to assess their impact across different soil types and climatic conditions.

ACKNOWLEDGEMENTS

The authors thank the staff of the Institute of Viticulture and Oenology, DLR Rheinpfalz, including the state winery, for their support in carrying out the experiments and for providing the experimental vineyards. We also thank the winegrowers for their valuable input in developing practical solutions for the implementation of cover crops under vines.

This work was funded by the “Forschungsring Deutscher Weinbau” (FDW).

REFERENCES

Abad, F. J., Marín, D., Imbert, B., Virto, I., Garbisu, C., & Santesteban, L. G. (2023). Under-vine cover crops: Impact on physical and biological soil proprieties in an irrigated Mediterranean vineyard. Scientia Horticulturae, 311. doi:10.1016/j.scienta.2022.111797.

Abbott, W. S. (1925). A method of computing the effectiveness of an insecticide. J. econ. Entomol, 18(2), 265-267.

Bavougian, C. M., & Read, P. E. (2018). Mulch and groundcover effects on soil temperature and moisture, surface reflectance, grapevine water potential, and vineyard weed management. PeerJ, 6, e5082. doi:10.7717/peerj.5082.

Chou, M. Y., Vanden Heuvel, J., Bell, T. H., Panke-Buisse, K., & Kao-Kniffin, J. (2018). Vineyard under- vine floor management alters soil microbial composition, while the fruit microbiome shows no corresponding shifts. Sci Rep, 8(1), 11039. doi:10.1038/s41598-018-29346-1.

Coniberti, A., Ferrari, V., Disegna, E., Dellacassa, E., & Lakso, A. N. (2018). Under-trellis cover crop and deficit irrigation to regulate water availability and enhance Tannat wine sensory attributes in a humid climate. Scientia Horticulturae, 235, 244-252. doi:10.1016/j.scienta.2018.03.018.

Fleishman, S. M., Eissenstat, D. M., Hoffer, G. M., & Centinari, M. (2023). Cover crops and a devigorating rootstock can impart substantial agroecosystem services to high-resource vineyards: A multi-year study. Agriculture, Ecosystems & Environment, 344. doi:10.1016/j.agee.2022.108287.

Ipach, R., Huber, B., Hofmann, H., & Baus, O. (2005). Richtlinie zur Prüfung von Wachstumsregulatoren zur Auflockerung der Traubenstruktur und zur Vermeidung von Fäulnis an Trauben. Outline for an EPPO-Guideline.

Londo, G. (1976). The decimal scale for releves of permanent quadrats. Vegetatio, 33(1), 61-64.

van Bruggen, A. H. C., Finckh, M. R., He, M., Ritsema, C. J., Harkes, P., Knuth, D., & Geissen, V. (2021). Indirect Effects of the Herbicide Glyphosate on Plant, Animal and Human Health Through its Effects on Microbial Communities. Frontiers in Environmental Science, 9. doi:10.3389/fenvs.2021.763917.