The effects of alternative herbicide-free cover cropping systems on soil health, vine performance, berry quality and vineyard biodiversity in a climate change scenario in Switzerland.

Serena Fantasia[1], Matteo Mota[2], Frédéric Lamy[3], David Marchand[4], Robin Sonnard[5], Nicolas Delabays[6], Vivian Zufferey[7], Beatrice Steinemann[8], Florine Degrune[9], Thierry Heger[10] and Markus Rienth[11*]

[1,2,3,9,10,11] Changins, Institute of Viticulture and Œnology, University of Applied Sciences and Arts Western Switzerland, Nyon, Switzerland
[4,5] FIBL, Research Institute of Organic Agriculture, Lausanne, Switzerland
[6] hepia, Earth-Nature-Environment Institute, University of Applied Sciences and Arts of Western Switzerland, Jussy, Switzerland
[7] Agroscope, Swiss Agricultural Research Institute, Nyon, Switzerland
[8] FIBL, Research Institute of Organic Agriculture, Frick, Switzerland

***Corresponding author:** markus.rienth@changins.ch

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Abstract

Herbicide-free soil management practices are needed to mitigate climate change, increase biodiversity and improve soil quality while minimizing detrimental effects on grapevine's stress tolerance and fruit quality. Within a multidisciplinary 4-year project we aim to a) evaluate the impact of cover crops on environmental and agronomic parameters and b) propose and develop innovative practices for different viticultural contexts in Switzerland. In the first phase we assessed 30 commercial vineyards across Switzerland, where growers are already using various herbicide-free soil management practices (permanent ground cover on the inter-row plus tillage on the under-vine, spontaneous vegetation or winter cover crops). In all plots, soil status, soil microbiome diversity, plant diversity and biomass, vine physiology and berry quality were assessed.
Amongst the tested treatments, winter cover crops appeared to be the most sustainable soil management option, assuring the ecosystem services provided by a cover crop while limiting nitrogen and water deficiency, as was the case of spontaneous vegetation. However, the installation and management of the cover crops need to be considered since detrimental effects on soil health might occur.

Introduction

In the search for a more sustainable viticulture, more and more winegrowers are converting to organic and/or biodynamic farming, renouncing to synthetic pesticides and herbicides. Herbicides are particularly questioned for their environmental and health impact and the legal constraints to their use are increasing the interest in reducing or eliminating their utilization. Currently an estimated 454'000 ha, corresponding to 6.4 % of world's vineyards are under organic production (OIV, 2021). In organic production, where herbicides cannot be used, weed control is a major challenge. This issue becomes even more challenging in vineyards which are difficult to mechanize, such as in steep or terraced vineyards.
The CV-VigneSol project aims to provide efficient, easy to install and to manage alternatives to herbicides. These solutions should require minimal interventions and preserve vineyard ecosystem as well as human health, without deteriorating vine physiology and berry quality. Currently, the implementation of innovative soil management practices by pioneering winegrowers is proceeding by trial and error. Scientific support is needed to quantify the impact of different soil covers on the vineyard ecosystem, on vine physiology, berry and wine quality and to propose solutions adapted to different pedoclimatic conditions.

Materials and Methods

The project is divided into three phases: 1) diagnosis, 2) on-farm and 3) on-station experiment. For the diagnosis phase, we selected 30 plots in 5 Swiss cantons (Geneva, Vaud, Neuchatel, Valais, Basel), characterized by different pedoclimatic conditions. Fifteen plots were located on mechanizable vineyards and fifteen on terraced vineyards. All plots were planted with Chasselas, the most abundant white variety in Switzerland, which is sensitive to water and nitrogen stress. Three soil management practices have been studied: 1) permanent ground cover on the inter-row plus tillage on the under-vine (i1: mechanized, i5: terraced); 2) spontaneous vegetation (i2: mechanized, i4: terraced); 3) winter cover crops (i3: mechanized, i6: terraced). The treatments (figure 1) were already in place before the beginning of the surveys.

Figure 1. Example of the three different soil management practices in mechanizable vineyards. From left to right: permanent ground cover on the inter-row plus tillage on the under-vine, spontaneous vegetation, winter cover crops.

To evaluate the effects of the three treatments on vineyard ecosystem and on the vine, the soil status, microbial communities, plant diversity and biomass, vine physiology and berry quality were investigated throughout spring and summer 2021.
Soil status included the assessment of soil compaction, root development, soil structure, earthworm biomass and ecological categories as well as the level of decomposition and integration of organic matter. Soil samples were collected from three different soil compartments: in the under-vine, under the wheel passage and in the middle of the inter-row. Physiochemical properties (pH, texture, porosity, organic matter, organic carbon, water retention, density) and microbial community composition were analysed from each sample.
Plant surveys were realized as described in Delabays et al. (2021). Soil cover was estimated and subdivided in plant cover, mulch, moss and bare soil proportions (figure 2.A). Plant community composition was also reported.
Vine physiology was determined through estimation of leaf-nitrogen content (N-tester®), bud fertility (number of grapes / number of shoots), yield estimation, vigor (30 shoots weighed / plot).
Two-hundred berries were randomly collected per plot, weighed, crushed and subsequently analyzed by WineScan® for sugars, organic acids, yeast assimilable nitrogen and pH. Must carbon isotope composition δ13C was analyzed to assess vine water status.
The phase 2) on-farm, started in 2022 and consists in a network of 10 vineyards. This experiment will allow us to evaluate the potential of several innovative herbicide-free treatments during three years. In parallel, the phase 3) on-station will allow us to assess the effects of different soil management practices in a highly-instrumented experimental plot at Changins (Nyon, Switzerland).

Results and discussion

Soil assessment

Soil analysis showed a large diversity of textures among the 30 parcels, ranging from plots with 5-10 % of clay in the canton Valais to 30-40 % of clay in canton Vaud. Soil compaction was higher in mechanizable vineyards

than in terraced vineyards, where no heavy machines are used. The compaction was a key factor for soil quality, negatively influencing several soil parameters such as the decomposition and abundance of organic matter, earthworm biomass, soil porosity and soil water retention. However, our results revealed no significant direct effects of the treatments on soil compaction.

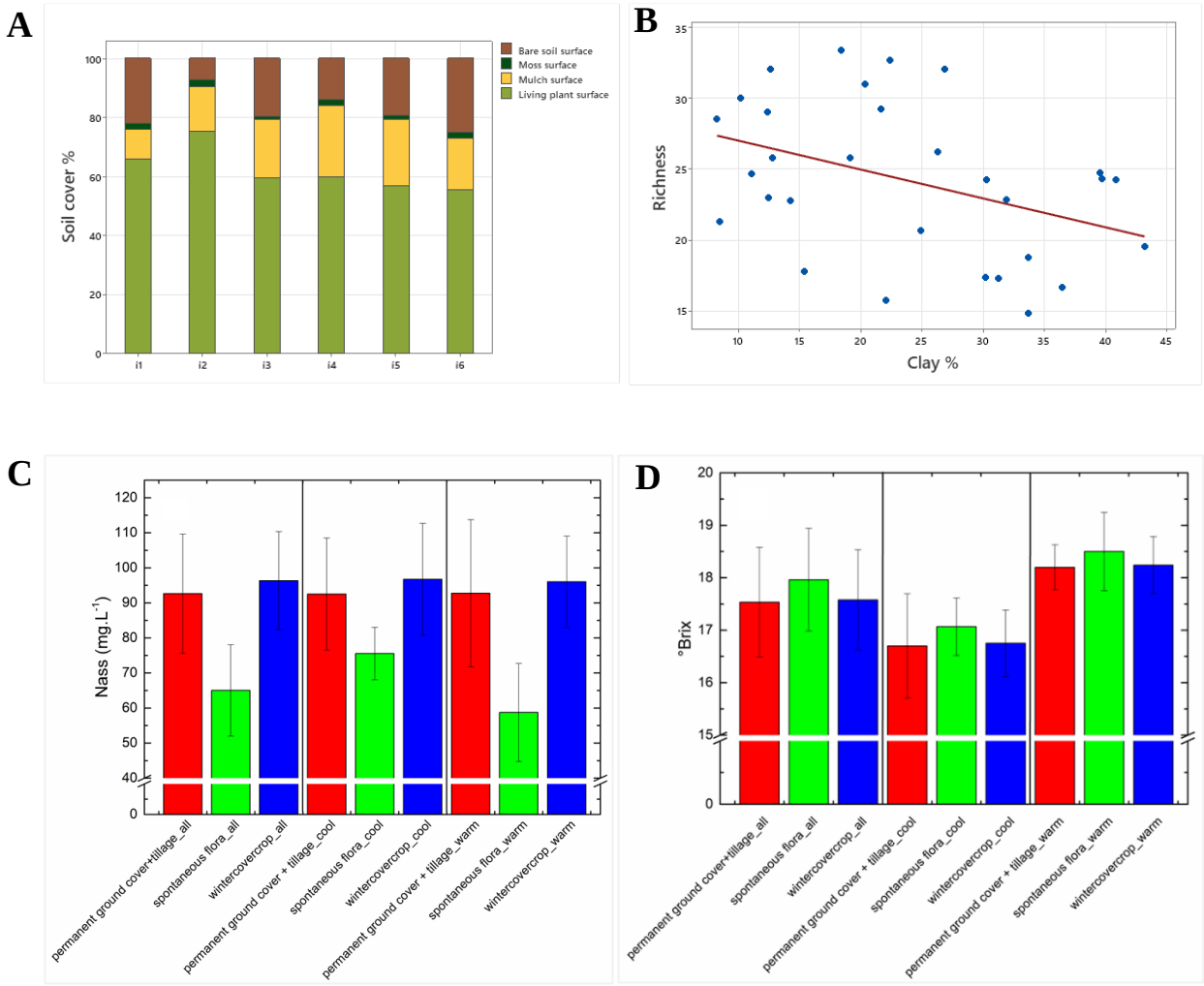

Figure 2. Influence of treatments on soil cover composition (A), influence of texture on plant species richness (B), effects of treatments on assimilable nitrogen (C) and Brix (D). Treatments specification. Figure 2.A: i1: permanent ground cover on the inter-row, plus tillage on the under-vine, i2: spontaneous vegetation, i3: winter cover crops (i1-i3: mechanizable vineyards); i4: spontaneous vegetation, i5: tillage on the inter-row and permanent ground cover on the under-vine, i6: winter cover crops (i4-i6: terraced vineyards). Figure 2.C and 2.D: "_all": average of all plots together; "_cool": average of plots situated in "cool" regions; "_warm": average of plots situated in "warm" regions, according to their accumulated growing degree days during the season.

Plant survey

The analysis of plant community composition and diversity showed a higher plant cover percentage in the "spontaneous vegetation" treatment (i2, i4), compared to the others (figure 2.A). This could potentially lead to a better soil protection from UV and extreme climatic events if compared with treatments with tilled under-vines (i1, i5) in which the soil is more bare and exposed. Regarding the species richness, 233 species have been identified on a total surface of 6'600 m^2, with an average of 27 species per plot. The treatments had no significant influence on species richness. The temperature and the soil texture were instead the driving factors, leading the plot location to become an important driver for plant diversity (figure 2.B).

Vine physiology and berry quality

The assimilable nitrogen content of grapes (Nass) was globally low in all plots, with most values below 100 mg N/liter, reflecting a nitrogen deficiency in the musts (Lorenzini, 1996). The sites with spontaneous vegetation

showed the lowest assimilable nitrogen values of all the treatments (figure 2.C). Water-nitrogen stress seems to be more important in this situation. The establishment of temporary plant cover in winter (winter cover crops), and the mechanical work of the under-vine (mechanical tillage) lead to a slight increase in the assimilable nitrogen content of the musts compared to the spontaneous vegetation. The measurements of the chlorophyll index (N-tester) indicated that the values are low (< 400) on all plots (Spring and Jelmini, 2002). The lowest values were observed on the spontaneous vegetation treatment, where ground evapotranspiration was the highest and the rainfall were the lowest.
The sugar content of the grapes did not significantly differ between treatments. Nevertheless, the plots with total ground cover (spontaneous vegetation) have slightly higher sugar levels than the other treatments (figure 2.D). A faster depletion of soil water reserves, in this case, could have caused mild water stress and favored the accumulation of sugars (Rienth and Scholasch, 2019). The results of carbon isotopic analyzes (δ13C) are lower than -26.5, showing an absence of water stress for Chasselas variety (Zufferey and Murisier, 2007).

Conclusion

This first phase of the project provides a general overview of the effects of different herbicide-free management practices on the vineyard ecosystem and vine physiology in a given pedoclimatic context. In the present study a spontaneous vegetation cover seemed to better protect the soil from erosion but competing more with the vine, in terms of nitrogen, than the other treatments. Under the investigated pedoclimatic contexts and in a relatively wet year, a winter cover crop appeared to be amongst the most promising solutions, representing a good compromise between sown cover crops and spontaneous vegetation, showing little mineral competition with the vine. However, repeated soil work during the year and an inappropriate soil preparation before sowing could increase soil compaction, a risk factor for resource protection and soil health. Reduced tillage and installation of a winter cover crop could enhance the services and reduce the disservices of cover crops.

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