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ORIGINAL ARTICLE

Sustainable soil management in the Badacsony Wine District

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Abstract – Agricultural landscapes with historical hillside vineyard cultivation have a touristic, economic, and environmental value in the Balaton uplands. However, sustainable cultivation methods are becoming increasingly important within today's adaptation to climate change impacts on these lands much exposed to erosion. Our long-term field experiment compared the effects of several soil-cover methods in several aspects. We recorded and examined the consequent changes in the physical (soil moisture), chemical (absorbable nitrogen content), biological (enzyme activity: fluorescein diacetate hydrolysis and dehydrogenase), the most probable number of bacteria and fungi), and economic (yield) parameters of soils. According to our results in 2017, mulching with organic plant wastes achieved the most positive effect on the parameters studied and also efficiently reduced erosion in the plantation.

Keywords – vineyard, cover crop, agricultural landscape management, soil biology, sustainability

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Introduction

Agricultural practices are continuous shapers of the environment and considerations such as agri-tourism, sustainable farming, and landscape management are only taken into account after the economic aspects. Historical agrarian landscapes having been farmed for hundreds of years can serve as tourist attractions in their own right, as well as maintain the traditions and lifestyles of local communities. Vine growing traditions of the Balaton Uplands go back to ancient times, but the cultivation practices and the use of lands have undergone significant changes, especially in the more recent times.

Nowadays, tourism brings the most revenue for the local population and it is also the most important source of income for businesses - as opposed to the previously dominant agriculture. Therefore it has become increasingly apparent to both local and national decision-making organizations that the preservation of the agricultural heritage has benefits that are unconditionally worthy of the central agricultural and rural development sources (Oláh 2014). In addition, agri-sector subsidies prefer and provide additional resources for farming practices that are environmentally friendly and preserve ecological conditions (Biagiol et al. 2012, MK 2014).

The vine growing culture of the Badacsony wine region involves farming on the slopes of volcanic hills which, in the course of soil cultivation, got gradually exposed to erosion, especially in the hill-valley orientation (Zanathy 1998, Varga and Májer 2004, Kirchoff et al. 2017). As a result of climate change, weather anomalies are becoming more and more frequent: this is primarily due to the uneven rainfall patterns that cause erosion (to which these areas are highly susceptible). However, there is a lack of information on the efficacy of soil erosion prevention methods that use natural or planted cover crops. More than a decade ago, researchers at the Viticulture and Oenology Research Station in Badacsony recognized this significant hiatus across Europe (Panagos et al. 2015, Rodrigo-Comino 2018) and established a long-term study on soil covering processes in a vineyard that was deliberately exposed to erosion. Their aim was to compare the efficacy and ecological aspects of these processes and to find answers for viticulturists looking for economic and ecological future ways of farming in this wine region.

In this paper, we publish the results of our studies in 2017. In 2017 sunshine duration was 20% higher than the multi-year average, while the levels of temperature and precipitation were close to that. Therefore, conclusions can be drawn not just for 2017 but generally for

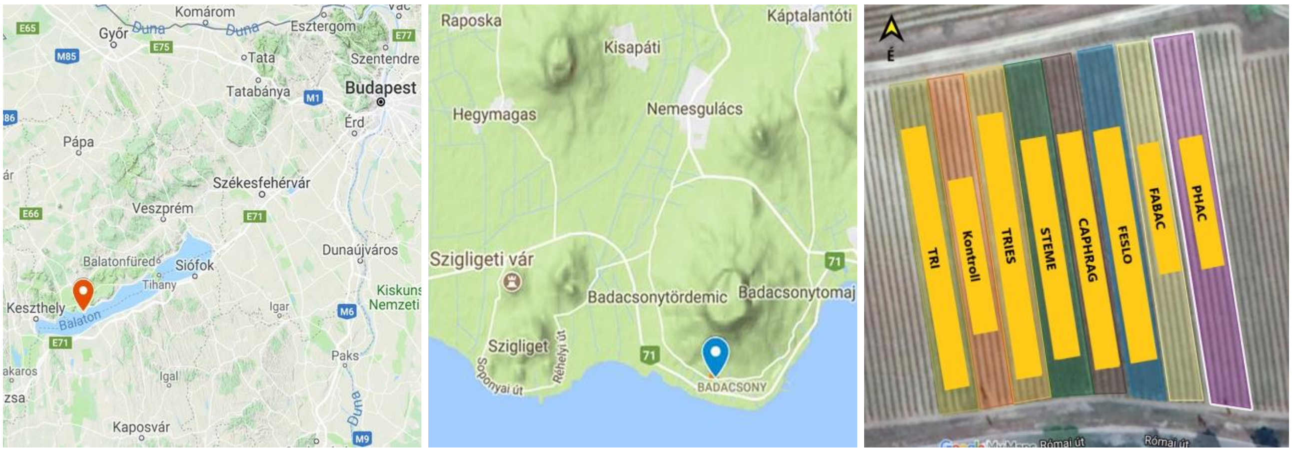

Figure 1. Location of fields and their treatments.

the typical climatic conditions of this wine region (Table 1).

Materials and methods

In the examined field four repetitions were set per treatment, all with 5 rows, each one in a total 0.1 ha area.

The plantation studied (Figure 1) is a Pinot Noir on T5C rootstock vineyard planted in 2001 with a north-south slope exposed to erosion, 12-14% mountain-valley (Varga and Májer 2018). The density of the plants is 5000 plants per hectare with midwire cordon system.

Table 1: Meteorological data of Badacsony SZBKI-NAIK (2017)

Month	Sunshine duration (hours)			Temperature (°C)			Precipitation (mm)		
	Average of many years	2017	Difference	Average of many years	2017	Difference	Average of many years	2017	Difference
January	63,9	100,0	36,1	-0,3	-5,1	-4,8	36,9	27,0	-9,9
February	94,6	97,0	2,4	1,7	2,5	0,8	39,5	61,9	22,4
March	150,3	235,0	84,7	6,3	9,3	3,0	37,8	12,2	-25,6
April	192,3	193,0	0,7	11,9	10,9	-1,0	44,1	22,4	-21,7
May	243,8	336,0	92,2	16,9	17,3	0,4	59,2	29,8	-29,4
June	256,0	306,0	50,0	20,2	22,4	2,2	74,0	71,7	-2,3
July	273,8	356,0	82,2	22,1	23,3	1,2	72,4	83,2	10,8
August	251,5	330,0	78,5	21,5	24,4	2,9	73,6	40,9	-32,7
September	188,5	168,0	-20,5	17,2	15,5	-1,7	53,4	123,0	69,6
October	143,8	181,0	37,2	11,9	11,7	-0,2	48,8	62,2	13,4
November	69,8	84,0	14,2	5,9	5,6	-0,3	61,0	61,3	0,3
December	47,0	99,0	52,0	1,3	2,6	1,3	46,4	72,0	25,6
TOTAL:	1975,3	2485,0	509,7				647,1	667,6	20,5
AVERAGE:				11,4	11,7	0,3			
Total during the vegetation:	1549,7	1870,0	320,3				425,5	433,2	7,7
Average during the vegetation:				17,4	17,9	0,5			

The following soil cover methods were used:
- CAPHRAG: organic plant waste (*Carex* sp.), reed (*Phragmites australis* L.), Canadian goldenrod (*Solidago canadensis* L.). Canadian goldenrod is a highly aggressive invasive species in the region of Lake Balaton. The mulched plant waste covers the surface in 30 cm thick layers. The cover needs to be renewed annually, and completely change it after 3 years (Varga and Májer 2004, Némethy et al. 2006).
- FESLO (durable vegetation): 40% red fescue (*Festuca rubra* L.), 20% perennial ryegrass (*Lolium perenne* L.), 20% various-leaved fescue (*Festuca heterophylla* L.), 20% tall fescue (*Festuca arundinacea* L.).
- FABAC (Fabaceae): 25% red clover (*Trifolium pratense* L.), 25% crimson clover (*Trifolium incarnatum* L.), white clover 25% (*Trifolium repens* L.), 25% common vetch (*Vicia sativa* L.), Pea (*Pisum sativum* L.)
- TRIES (periodic vegetation): winter wheat (*Triticum aestivum* L.).
- TRI (seasonal vegetation): triticale (*Triticum secale* L.).
- STEME (typical composition of weed of the area). In the order of the end of spring and spring-summer vegetation), the following species: *Stellaria media* L., *Lamium amplexicaule* L., *Capsella bursa-pastoris* L.
- PHAC: phacelia (*Phacelia tanacetifolia* L.).
- CONTROL (mechanical tillage with disc-plough (three times during the vegetation period).

We received the meteorological data from the automatic meteorological station of the SZBKI-NAIK.

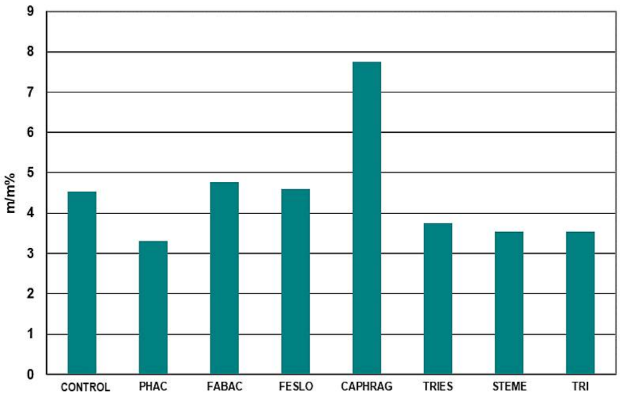

Figure 2. Effects of cultivation methods on soil moisture (2017).

In our soil biology studies we used literature methods to determine the enzyme activities of dehydrogenase (DH; Alef 1995) and fluorescein diacetate hydrolysis (FDA; Adam and Duncan, 2001), and the most probable number of bacteria and microscopic fungi (MPN; Szili-Kovács et al. 2009, Dudás et al., 2017) in two seasons (spring and summer). Soil samples were taken from three sites along the slope (top, middle and foot parts) at the depths of 10-30 and 30-50 cm. The biological parameters were not investigated in the top ten centimeters of the soil in order to avoid the direct distorting influences of the roots of the cover crop. In addition, grape plants are deep-rooted: the top 10 cm layer of the soil does not play a significant role in the plant’s nutrient and water absorption (Bényei et al., 2005).

Results and discussions

Our test results showed a higher value of soil moisture in the mulch cover experiment (CAPHRAG) (more than m/m 3% higher) compared to the other soil covering and treatment modes. Similarly, in the 10-30 cm layer the amount of the absorbable nitrogen was five times higher as compared to the other seven (Figure 2).

In the quantitative numbers of crop yields, we got outstanding results in the CAPHRAG with FABAC and PHAC parcels compared to CONTROL (Varga and Mayer 2018). In the case of PHAC treatment we had a lower level of soil moisture than in the control – in contrast to the other two – but nonetheless, vines could give a similar yield level.

Among the two enzyme activity and the two density measurements (MPN and DH) for the bacteria had the highest correlation level (0.7407), while the FDA and bacteria had 0.1944. This correlation between bacterial density and DH is in line with the ones laid out by Wolińska et al. (2015). As they concluded, in the upper twenty centimeters of agricultural soil cultivation decreases both in agrarian areas.

Among the eight treatments, cluster analysis performed on biological parameters by IBM-SPSS 'between-group' method CAPHRAG and STEME clearly separated from the other six (Figure 3).

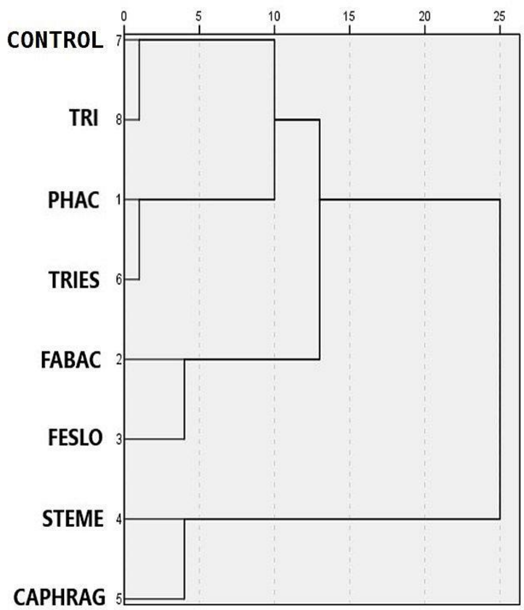

Figure 3. Dendrogram – cluster analysis (biological data from both depth and sampling date), between groups-method (IBM-SPSS)

Based on our results we concluded that CAPHRAG is a highly effective tool for preserving soil moisture content. This has a beneficial effect both on the nutritional capacity of grape plants and on the soil biota activity and also enhances the mobilization of nitrogen. Most importantly, it provides adequate protection against soil erosion.

Loss of soil fertility and biodiversity is known to be accelerated by soil erosion (Novara et al., 2019). Adoption of nature-based solutions (like cover crops or mulching) for soil management can sustain grape productivity by saving soil moisture and maintaining a number of ecosystem services (Keesstra et al., 2018).

In order to get further answers to our questions, we are planning to continue this field study using the same treatments and measuring the same parameters. In addition, we are planning to carry out molecular biological analyses on samples from the rhizosphere to obtain qualitative and quantitative data on microflora and fauna communities of the vineyard. The results may help us to identify a sustainable cultivation method that is to be applied in Badacsony wine district.

Open access statement

Public interest statement

This paper is written to publish data from a long-term field examination made on a traditional viticultural region. Badacsony wine district already has serious challenges with erosion and soil water management that are accelerated by climate change and the use of unsustainable cultivation methods.

Acknowledgments

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