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Comparison of species-rich cover crop mixtures in the Tokaj wine region (Hungary)

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Abstract Intensive agricultural practices of past decades—such as mechanical cultivation on steep vineyard slopes—can endanger soil fertility. In addition, climate change scenarios predict heavier rainstorms, which can further accelerate soil degradation. Therefore, the use of cover crops in the inter-row has a special importance, particularly on steep slopes and in organic agriculture. A species-rich cover crop mixture helps not only in preventing erosion and providing easier cultivation, but has also positive effects on soil structure, soil fertility and ecosystem functions (Bauer et al. 2004; Hofmann et al. 2008). We began to develop and test several species-rich cover crop mixtures in spring of 2012 in Hungarian vine regions. During the experiments, three species-rich cover crop mixtures (Biocont-Ecovin mixture, mixture of legumes, mixture of grasses and herbs) were compared in vineyards of the Tokaj vine region. Each mixture was sown in three subsequent inter-rows at each site of the experiment. In the control blocks, unsown inter-rows and mechanically cultivated inter-rows were located subsequently next to each other. We studied weed control, yield quantity and must quality in every treatment. We found that the cover of weeds was lower in every treatment compared to the unsown control plots for 2013; thus, cover crops suppressed the weeds of the inter-rows effectively. Most examined indices of grapevines were not significantly affected by the applied cover crops. However, the yield loss results show that under Hungarian climate, the soil coverage in every second inter-row is more recommendable than subsequent seeding, where total erosion control is not required. The interest of the vine growers shows the importance of the topic; thus, we involved other wine regions of Hungary in our further experiments.

Keywords Cover crop · Vineyard · Erosion · Organic

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Introduction

Mechanical cultivation is one of the most frequently applied soil management techniques in Hungarian vineyards (Bényei et al. 1999) However, its too frequent or improper application can result in several negative effects such as soil desiccation due to the higher

evaporation, decayed soil structure, erosion and nutrient loss (Aljibury and Christensen 1972; Bauer et al. 2004; Dijck and Asch 2002; Diófási et al. 2000). Improper mechanical soil management can also lead to long-term topsoil and subsoil compaction (Ferrero et al. 2005; Zanathy 2006). Preserving soil moisture is especially important in arid regions—such as many parts of Hungary—with less than 500 mm of precipitation per year. It has an especially high importance during summer, when evapotranspiration can be higher than precipitation (Bauer et al. 2004). Since the growth of the roots is influenced by soil structure, the growth of the vine is also related to the soil compaction and moisture (Wheaton et al. 2008).

Alternative soil management techniques, such as applying different cover materials on the soil surface, can help to sustain a favourable water balance and soil structure (Ramos and Martinez-Casanovas 2006). Several materials (e.g. straw, reed or sedge) or cover crops can be used for soil covering. In this paper, we focus on cover crops. The application of living mulch has many agronomic advantages, including the control of weeds and erosion as well as the improvement of the physical structure of the soil. Mulching reduces the need for frequent soil tillage in agroecosystems. It protects the soil like an umbrella from heavy rainstorms, thus considerably reduces erosion (Schuch and Jordan 1981; Rinaldi et al. 2000; Varga and Májer 2004). There are other reasons why we need coverage in the inter-rows, especially in organic farming: due to cover crops, we can enhance soil microbial activity, fertility and soil structure (Bauer et al. 2004; King and Berry 2005). With the use of cover crops, we can gain erosion control (Louw and Bennie 1992; Fourie 2010), and an inter-row with cover crops can be walked through all year (Bazoffi and Chisci 1999; Celette et al. 2005), which is important as frequent spraying may be needed in biological pest management (Hofmann et al. 2008). Finally, with the

Table 1 Species composition (weight %) of the seed mixtures

Common name	Latin name	Biocont-Ecovin mixture	Grass-herb mixture	Legume mixture
Bird's-foot-trefoil	*Lotus corniculatus*	2.7	10	15
Black medick	*Medicago lupulina*	16.2	10	15
Bladder campion	*Silene vulgaris*		1.5	
Brown knapweed	*Centaurea jacea*		1	
Buckwheat	*Fagopyrum esculentum*	8.1		
Common sainfoin	*Onobrychis viciifolia*	37.3		15
Common vetch	*Vicia sativa*	16.2	10	10
Common yarrow	*Achillea millefolium*		1.5	
Cornflower	*Centaurea cyanus*		1	
Crown vetch	*Coronilla varia*		10	10
Fescue	*Festuca rupicola*		30	
Lacy phacelia	*Phacelia tanacetifolia*	2.7		
Lady's bedstraw	*Galium verum*		1.5	
Narrowleaf plantain	*Plantago lanceolata*	1.1	10	5
Perennial flax	*Linum perenne*		1.5	
Red clover	*Trifolium pratense*		5	15
Small burnet	*Sanguisorba minor*	0.5		
White clover	*Trifolium repens*	8.1	5	15
White mustard	*Sinapis alba*	5.4		
Wild carrot	*Daucus carota*	1.6		
Woodland sage	*Salvia nemorosa*		1.5	
Species number		11	15	8

Table 2 The sites of the experiment

Vineyards	Year of planting	Year of sowing	Growing space (m^2)	Stocks/hectar	Certified ecological vineyard	Variety
Gróf Degenfeld	2009	2012	1.44	6944	Yes	Furmint
Tokaj—Oremus/Budaházi	2007	2012	1.76	5682	No[a]	Furmint
Tokaj—Oremus/Szentvér	2007	2012	1.76	5682	No[a]	Hárslevelű
Tokaj—Hétszőlő Zrt.	1994	2012	1.80	5556	Yes	Furmint

[a] 30 % of the vineyard is protected by biological pest management

use of cover crops in organic viticulture, we can add aesthetic value to a vineyard, which is quite important in ecotourism.

However, cover crops might also have negative effects on the vine performance since they may compete with the vine for water and nutrients (Steinberg 1981; Fardossi 2002). Wine regions characterised by low precipitation are not always suitable for permanent cover crops, because of the intense competition for water between the vine and species in the cover crop. In such cases, a lower vine performance can be observed. Maintaining a good soil structure is important in order to minimize such competition. Plant species of an optimal cover crop mixture should therefore have different root structures, which can form an optimal soil profile of the inter-rows (Hofmann et al. 2008).

In Hungary, cover cropping has been studied in vineyards more intensively since the last 10–15 years (Varga et al. 2007; Göblyös et al. 2011). Many seed mixtures were used and tested, but most of them contained non-native species or native species from non-Hungarian provenance. Many studies found that species and even ecotypes of a local provenance can establish and cope better with local environmental conditions (Mijnsbrugge et al. 2010). Thus, our aim was to develop well adapted and diverse cover crop mixtures for Hungarian vineyards by using native species, whenever possible from Hungarian provenance. We studied the effects of cover crop seed mixtures on the cover of weeds and on the yield and must quality.

Materials and methods

The studied vineyards were situated in the Tokaj region, Northeast Hungary. Four sites were involved in the study (Tables 2 and 3): Hétszőlő (Tokaj), Gróf Degenfeld (Tarcal) and two sites in Oremus (Tolcsva; Szentvér and Budaházi sites). The open-field trials were set up in spring of 2012. Three seed mixtures were used: Biocont-Ecovin, grass-herb and legume seed mixtures. Biocont-Ecovin seed mixture is a commercial seed mixture produced by Biocont Hungary Ltd (László 2011). Grass-herb and legume seed mixtures were composed by the Hungarian Research Institute of Organic Agriculture (ÖMKi, www.biokutatas.hu) after consulting with vine growers and ecologists. The species composition of seed mixtures is demonstrated in Table 1. Biocont-Ecovin mixture contained 12 forb species, grass-herb mixture contained 15 forb and 1 grass species and legume mixture contained 9 forb species. In the Ecovin seed mixture, there are species

Table 3 Soil characteristics of the vineyards

Site	pH (KCl)	$CaCO_3$-N mg/kg	Humus %	Soil water capacity	NO_3-N mg/kg	P_2O_5 mg/kg
Gróf Degenfeld	6.22	0.2	1.68	43	4.14	312
Tokaj—Oremus/Szentvér	5.29	0	0.89	51	2.18	85.62
Tokaj—Oremus/Budaházi	5.54	0	1.6	51	4.28	307.31
Tokaj—Hétszőlő Zrt.	7.47	5.8	1.11	43	12.47	166.9

Table 4 Floor management of the vineyards

Vineyards	Mixtures	Control	
	Treatments of the sown inter-rows	Treatments of the control inter-rows	Mown inter-rows
Gróf Degenfeld	Rolling	Mechanical weed control (2–3 times with cultivator)	Mowing (2–3 times)
Tokaj—Oremus/ Budaházi	Mowing before harvest		
Tokaj—Oremus/Szentvér	Mowing before harvest		
Tokaj—Hétszőlő Zrt.	Rolling		

that are widely used in cover cropping. The disadvantage of Ecovin seed mixture is that there are species in it that are non-native in Hungary. The legume seed mixture consists mainly of legume species in similar composition percentage and Plantago lanceolata. In the grass-medical forb seed mixture besides the legume species and Plantago lanceolata, there is a fescue species with quite high composition percentage, and many species with low composition percentage that are desirable from a biodiversity conservational point of view.

The studied vine varieties were 'Furmint' (Hétszőlő, Degenfeld, Oremus—Budaházi) and 'Hárslevelű' (Oremus—Szentvér) (Tables 2 and 3). Each seed mixture was sown in three adjacent inter-rows in March 2012. Three unsown inter-rows (mechanical cultivation and mown inter-rows adjacent to each other) were designated as control at each site. The floor management of the sites is summarised in Table 4. We recorded the percentage cover of vascular plants in the middle-sown and control inter-rows in five 1 × 1-m permanent plots late June 2012 and 2013 (Table 5). We classified species as sown species and weeds (all unsown species were considered as weeds). Besides botanical measurements, yield and

Table 5 Average cover (%) of weeds and average total cover in the inter-rows sown with the three seed mixtures and control in 2012 and 2013

2012	Biocont-Ecovin	Grass-herb	Legume	Control
Total cover				
Gróf Degenfeld	69.0^{a}	69.0^{a}	80.6^{a}	47.0^{b}
Tokaj—Oremus/Budaházi	37.0^{ab}	39.6^{a}	58.6^{a}	11.0^{b}
Tokaj—Oremus/Szentvér	66.0^{ab}	94.0^{a}	94.0^{a}	26.0^{b}
Tokaj—Hétszőlő Zrt.	88.0^{a}	87.0^{a}	73.0^{ab}	23.4^{b}
2013				
Gróf Degenfeld	88.6^{ab}	96.6^{a}	94.0^{a}	77.0^{b}
Tokaj—Oremus/Budaházi	86.4^{a}	94.6^{a}	96.2^{a}	38.4^{b}
Tokaj—Oremus/Szentvér	86.0^{a}	87.0^{a}	62.0^{b}	46.0^{c}
Tokaj—Hétszőlő Zrt.	79.0^{a}	76.0^{ab}	75.6^{a}	32.8^{b}
Weed cover				
Gróf Degenfeld	38.4^{a}	58.1^{a}	38.8^{a}	44.4^{a}
Tokaj—Oremus/Budaházi	1.0^{a}	19.4^{b}	11.6^{ab}	11.0^{ab}
Tokaj—Oremus/Szentvér	11.1^{a}	18.9^{a}	26.0^{b}	26.1^{b}
Tokaj—Hétszőlő Zrt.	71.4^{a}	84.0^{a}	65.0^{ab}	22.6^{b}
2013				
Gróf Degenfeld	56.2^{a}	34.0^{b}	15.9^{b}	74.5^{a}
Tokaj—Oremus/Budaházi	0.5^{ab}	1.6^{ab}	0.1^{a}	36.4^{b}
Tokaj—Oremus/Szentvér	26.8^{a}	2.5^{b}	5.3^{b}	44.9^{a}
Tokaj—Hétszőlő Zrt.	46.1^{a}	7.5^{b}	47.4^{a}	32.0^{a}

Significant differences are marked with superscript letters (one-way ANOVA, Tukey test, $p < 0.05$)

Table 6 Average yield of the stocks (kg) in 2012 and 2013

	Biocont-Ecovin		Grass-herb		Legume		Control	
	2012	2013	2012	2013	2012	2013	2012	2013
Gróf Degenfeld	1.43	2.2	1.42	2.22	1.39	2.02	1.65	2.31
Tokaj—Oremus/Budaházi	1.74	2.08	1.51	1.96	1.21	2.07	1.27	2.22
Tokaj—Oremus/Szentvér	1.34	3.13	1.1	3.4	0.82	3.33	1.57	3.69
Tokaj-Hétszőlő Zrt.	1.34	1.96	1.28	1.8	1.15	1.76	1.56	2.43

The statistical analysis (one-way ANOVA, Tukey test, $p < 0.05$) did not show significant difference among the measured indices

must quality were studied in every treatment. The yield was measured by picking all the grapes of ten zigzag-chosen vines in each block. At each site, differences in yield quantity, total cover and cover of weeds between treatments were analysed using one-way ANOVA followed by the Tukey tests for mean comparison. From the harvested ten vines/treatment, one must sample/treatment was pressed: sugar content (MM°) and titrable acidity (g/l) of the must were measured in the laboratory of the Research Institute of Oenology and Viticulture, Tokaj wine region.

Results

At most sites, total plant coverage scores in sown inter-rows were not significantly different, either in 2012 or 2013. However, in the control inter-rows, the total coverage was significantly lower than in most sown inter-rows, both in 2012 and 2013 (Table 4). In 2012, we could not find clear trends in the cover percentage of weed species. However, the lowest weed cover scores were recorded mainly in inter-rows sown with Biocont-Ecovin seed mixture, while the highest weed cover scores were recorded in inter-rows sown with grass-herb seed mixture. In most cases, these differences were not significant. In 2013, the cover of weed species was significantly lower at almost every site in inter-rows sown with grass-herb and legume seed mixtures compared to control inter-rows. The type of applied seed mixture did not have significant effect on the amount of yield. We found slightly higher yield in the control blocks but this difference was not significant (Table 6). In case of the must quality (sugar content and titrable acidity), we did not find significant differences between the four treatments (Tables 7 and 8).

Discussion

Our results suggest that sowing high-diversity seed mixtures can result in durable cover crop vegetation that can establish successfully on the different sites. The shortage of precipitation influences the development of the canopy, especially when the drought occurs in the first part of the vegetation period, when the water demand of the plants is high (Escalona et al. 2003). In our study, we did not find significant differences between treatments

Table 7 Quality of the must in 2012

	Biocont- Ecovin		Grass-herb		Legume		Control	
	MM°	g/l	MM°	g/l	MM°	g/l	MM°	g/l
Gróf Degenfeld	20.3	6.5	22	5.1	21.4	5.9	20.8	6.3
Tokaj—Oremus/Budaházi	21.2	6.1	21.9	7.6	22.7	6.8	24.1	7.8
Tokaj—Oremus/Szentvér	21.4	6.6	18.9	6.4	20.8	6.4	21.9	6.3
Tokaj—Hétszőlő Zrt.	23.3	6	22.8	5.5	21.6	5.9	23	6.9

Notations: Sugar content (MM°) and titrable acidity (g/l) of the must samples of 2012

Table 8 Quality of the must in 2013

	Biocont-Ecovin		Grass-herb		Legume		Control	
	MM°	g/l	MM°	g/l	MM°	g/l	MM°	g/l
Gróf Degenfeld	18.8	8.3	20.1	8.3	20.1	8.3	20.1	8.5
Tokaj—Oremus/Budaházi	22.9	9	21.6	9	22.9	8.9	22.9	9
Tokaj—Oremus/Szentvér	21.2	7.8	21.2	8.4	21.2	10.8	20.8	8.2
Tokaj—Hétszőlő Zrt.	24	8.2	21.4	7.8	24	8.8	23.5	8.1

Notations: Sugar content (MM°) and titrable acidity (g/l) of the must samples of 2013

regarding yield quantity and quality, which is a promising result. A slight decrease of yield was, however, recorded, especially in young plantations.

This suggests, in accordance with the literature, that in case of young vines, permanent cover cropping is not recommended because of potential water competition, and other options, such as mulching (e.g. straw, reed or sedge) or using seasonal cover crops can be more beneficial (Schuch and Jordan 1981; Rinaldi et al. 2000; Varga and Májer 2004). These results can help vine growers to test optimal cover crop floor management in their vineyards, depending on the age of the grapevines, and in consideration of edaphic and climatic conditions. If wine growers are nevertheless concerned by yield loss, it can be suggested to conduct sowing of only every second inter-row—provided that erosion control is not highest priority.

Conclusions

Our results show that all tested cover crops were established successfully in the inter-rows, and weed cover was lower in most sown inter-rows than in control plots. We could not find significant differences between treatments regarding yield quality and quantity. Although there was a slight decrease in yield quantity, this was not significant.

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