HUNGARIAN UNIVERSITY OF
AGRICULTURE AND LIFE SCIENCES

Thesis of Ph.D. dissertation

Biological, agrochemical and –physical characterization of vineyards rhizosphere related to the applied cultivation methods

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Keszthely

2021

The Doctoral School

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1. Antecedents and objectives of the work

When compiling my research plan, I formulated the task of **collecting data** on several vineyards in the Balaton Wine Region with different soil types and cultivated methods. The aim was also to supplement the "extended" agrochemical studies examining the physicochemical parameters of the soil with more extensive and **gap-filling biological studies**.

Exploring the effects of cultivation methods on the soil, as a multi-phase medium and its living community, provides an opportunity to formulate proposals and to develop economically and ecologically advantageous (more) farming and tillage practices.

Based on the above, I aimed to investigate the following effects:

- Cultivation of different intensities involves different degrees of soil disturbance. Does this affect the physical, chemical and biological characteristics of the 10-60 cm soil zone, which includes the most significant part of the root mass of the grapes?
- Do the different soil cover and cultivation practices applied in the vineyards affect the exposure of the given area to erosion, the physical, chemical and biological parameters of the soil?
- An innovative Hungarian invention is the "soil ventilation" machine, which is able to create a looser and richer air in the plantations (at a depth of 60 cm) without disturbing the topsoil, what changes can it cause? In an experiment we set up, we studied the effect by indirect methods on the species composition of the fungal community of the rhizosphere and on the development of certain physical and agrochemical properties.
- Individual treatments and cultivation practices affect the species diversity and function of fungal and bacterial communities in the grape root system. We hope to evaluate the properties of the rhizosphere with conventional and 21st century technological laboratory testing methods and statistical and bioinformatics analyses to help evaluate them, and we hope to formulate proposals for practical application.

2. Material and method

2.1. The plantations examined

2.1.1. Comparison of tillage practices - 'Hajagos Hill'

Hajagos Hill is part of the Badacsony wine region, a vineyard on the "skirt" of the mountain, with a floor area of 6.96 ha, which has been divided into three areas of 3.39 ha, 1.84 ha and 1.73 ha respectively due to the change of ownership following the change of regime. On September 6, 2017, the representatives of the company operating under the name *Talajszelloztetes.hu* carried out soil aeration and loosening on an experimental basis in certain parts of the three plantations. In the experiment, compressed air generated by a compressor at a depth of 60 cm is delivered at high pressure without disturbing the soil. The potential effects of this treatment were also examined separately in the 3 different cultivation modes.

Biodynamic cultivation: The 1.73 ha of Pinot noir vineyard under biodynamic (hereinafter: B) conversion, with a year-round, alternating row spacing, has a soil cover consisting of local weed flora, which is kept in the desired condition by mechanical mowing in both rows and row spacing. . In the year preceding the surveys, medium-deep loosening was carried out in the plot. Only spray (surface, non-absorbable) spray of biological, sulphur and orange oil and insect pests with biological effects against fungal pathogens is used.

Organic cultivation: In the 1.82 ha Muscat Ottonel plantation called organic (hereinafter: Ö), the row spacing is covered every two rows by permanent vegetation consisting of the local weed flora. Rows subject to mechanical cultivation are cultivated with a cultivator. The bottom of the rows is kept weed-free with a rotary harrow cultivating. Plant protection is carried out as required with contact copper and sulphur active ingredients, as well as with natural adjuvants and plant conditioning supplements that can be used in organic farming.

Integrated cultivation: The rows of the 3.39-hectare integrated (hereinafter: I) Kéknyelű plantation are characterized by intermittent weed cover every two rows, which is kept low with a tillage cultivator, and weeds are ensured with a harrow rotating in the cultivated rows. In addition to total and soil herbicide use, mowing is also used in the rows. They protect against insect and fungal pests of grapes with a combination of systemic and contact agents.

2.1.2. Long-term cover and tillage experiment - ‘Badacsony’

For more than a decade, the NAIK research station in Badacsony set up a long-term experiment comparing soil cover methods on a plantation planted in an eroded area, the results of which are presented in this dissertation. A treatment has 5 row spacing, for a total of 0.1 ha of treatment area. The plantation is subject to erosion, with a north-south slope, 12-14%, in a mountain-valley direction, with medium-high cordon cultivation.

The seven soil cover procedures and control treatments used are as follows:

- FAC: Phacelia (*Phacelia tanacetifolia* L.),
- PILL: mixture of legumes: Red testis 25% (*Trifolium pratense* L.), Purple clover, 25% (*Trifolium incarnatum* L.), White clover 25% (*Trifolium repens* L.), Spring vetch, 25% (*Vicia sativa* L.), Fodder peas (*Pisum sativum* L.),
- FES: permanent vegetation cover, special grass mixture: 40% *Festuca rubra* L., 20% *Lolium perenne* L., 20% *Festuca heterophylla* L., 20% Cane *Festuca arundinacea* L.),
- TAK: organic plant waste: sedge (*Carex hirta* L.), reed (*Phragmites australis* L.), Canadian goldenrod (*Solidago canadensis* L.),
- TER: area-specific weed composition: in the order of quantity and appearance of late winter-spring-early summer vegetation: Hen string (*Stellaria media* L.), Velvet orchard (*Lamium amplexicaule* L.), Shepherd's bag (*Capsella bursa-pastoris* L.),
- BU: seasonal vegetation cover: Winter wheat (*Triticum aestivum* L.),
- MEC: mechanical tillage control: discing,
- TRI: seasonal vegetation cover: Triticale (*Triticum secale* L.).

2.1.3. Tillage intensity comparison - ‘St. George’s Hill’

The study was performed in three adjacent vineyards. In one of them **intensive**, in the other **extensive** mechanical tillage is used, while in the third area **abandoned**, only mowing is carried out on it.

The age of low-capital plantations planted uniformly on the T.5C rootstock with the noble grape variety Müller Thurgau is uniformly over thirty years.

INT, intensive: In the intensive cultivation plantation, discing took place 4 times a year in the years preceding the study, ie soil disturbance in the upper 20 cm of the soil. Plant protection is carried out exclusively with contact pesticides. Soil nutrient replenishment from external sources has not occurred in the last 5 years.

EXT, extensive: In the extensive cultivation, mechanical tillage was carried out twice a year in the years preceding the study (tillage with a rotary harrow at a depth of 0-20 cm). Plant protection is also carried out exclusively with contact pesticides. Soil nutrient replenishment from external sources has not occurred in the last 7 years.

AB, abandoned: The abandoned plantation has not been subjected to soil disturbance operations for more than 10 years prior to the tests. There have been no plant protection, canopy management, soil nutrient replenishment from external sources in the last 10 years.

2.2. Parameters tested per area

	Tillage procedures - 'Hajagos-hegy'	Intercultural cover and tillage - 'Badacsony'	Tillage intensity - 'Szent György-hegy'
Soil mechanical composition	X	X	
Quartz sand content			X
Gravimetric soil moisture	X	X	
Soil moisture and near - surface temperature		X	
Soil water holding capacity (pF)	X	X	
Aggregate stability	X	X	
Penetration resistance	X	X	X
Advanced soil and plant analysis	X	X	X
Measurement of enzyme activities	X	X	
Culture mycology			X
PCR - from pure cultures			X
Nextgen metagenomics	X	X	

2.3. Test methods

2.3.1. Sampling

3-3 soil samples per area and per treatment, and 5-5 soil samples weighing approximately 500 g each were taken from the edges of the vineyards, drilled at a distance of 25 cm from the vine with a hand-held soil drill for 10-20 and 30-40 cm range for the study of edaphone, while at depths of 0-30 and 30-60 cm to

perform agrochemical studies. These samples were then homogenized to give 1-1 samples per depth per treatment, and laboratory tests were performed on them.

2.3.2. Investigation of physicochemical properties of soils

Mechanical composition of soils: The mechanical composition was determined by a fast and accurate, automated measurement method, the measurement method with a laser particle analyser.

Silica sand content - determination of phylloxera immunity: The test was performed according to the standard MSZ-08-0010:1978, Determination of soil immunity and physiological lime content.

Examination of the actual moisture content and bulk density of the soil: The examination of the actual moisture content and bulk density of the soil was performed by gravimetric method.

Soil moisture and near-surface temperature monitoring: The sensors measured four parameters every 15 minutes (soil moisture, air temperature, light: photosynthetically active radiation (PAR) and soil conductivity). From the data thus obtained, soil moisture (range: 0-50 [v/v%]; accuracy: +/- 3%) and near-ground temperature (range: -5 ° C to +55°C; accuracy: +/- 1,5 ° C) data were used.

Soil water holding capacity (pF): Water retention tests were performed using the Richards method with ceramic-based extractors. Using the measured bulk density values, the volume percentage moisture content values for each pF point (0, 2.5, 4.2) were determined. Finally, using the previous data, we calculated the potential values of each moisture fraction (gravitational water (GV), disposable water (DV), unavailable water (HV)).

Aggregate stability: In our studies, the degree of water resistance of soil aggregates was determined based on the modified Kemper-Rosenau wet sieving method.

Penetration resistance: Soil penetration resistance was measured at a depth of 0-80 cm with an Eijkelkamp Penetrologger.

Extended soil and plant analysis - accredited test series: The extended soil and plant test was performed by the Laboratory of the NAIK-SZBKI Badacsony Research Station with the tools and methods according to the accreditation.

3. Main results

3.1. Impact of tillage practices on biotic / abiotic factors of the vine rhizosphere - 'Hajagos Hill'

Based on the results of the **soil moisture content**, we found that the disposable water content (DV) for grapes was the highest in the biodynamic (B) treatment, but based on the gravimetric test method, we did not find any significant differences between the different cultivation methods.

Under the effect of **soil aeration**, DV values were found to be higher in the samples taken with the loosened (L) treatment, without exception, at both A (0–30 cm) and F (30–60 cm) depths. However, soil aeration did not reduce compaction.

Aggregate stability values, in addition to the negative effect of more intense soil disturbance, reduced the percentage of stable aggregates for each pesticide (specifically herbicides and insecticides) used exclusively in integrated (I) treatment.

Soil aeration, by increasing the air and oxygen content of the soil, resulted in clearly increasing values in the amount of stable aggregates in the integrated (I) and biodynamic (B) treatments. The effect was examined one and a half years after the treatment, so the condition experienced at that time can be said to be stable and not just intermittent.

The integrated (I) treatment (number of turns, tillage methods resulting in compaction) resulted in significantly higher compaction and soil resistance values, and this loosening due to soil aeration did not help either.

We measured the extent of biological activity primarily related to organic matter content by **DHA** enzyme analysis. A positive correlation was expected. DHA activity was found to be the highest for both NL and L treatments in plantation B, in line with previous expectations.

The results of the **FDA** enzyme activity assay, which is also used to index the amount available substrate in the soil, may be indirectly positively related to the amount of organic matter-degrading saprophytic organisms and the ability of these microbes in mineralization processes. We also found a positive correlation between FDA activity and aqueous pH, as well as Mg and P content.

Nextgen, shotgun metagenomic studies present in more detail than ever before the species level, identifying the constituents of the grape rhizosphere fungal community in the patterned treatments. Treatment I contained a much higher proportion of DNA from pathogenic strains. The species whose dominance alone significantly modified the rate of treatment was *Neonectria ditissima* (syn.

Neonectria galligena), a more widely known anamorphic, asexual form called *Cylindrocarpon heteronema*. In the study of abundance, the other three species that followed were also pathogenic fungi. The proportion of fungal species classified as antagonists was balanced between cultivation methods, but the proportion of symbionts showed greater variability.

From the results of the **leaf analysis**, based on the nitrogen and potassium supply, it can be said that the worst nutrient supply indicators had treatment I.

3.2. Results of row cover and tillage in a plantation exposed to erosion

Gravimetric soil moisture data for FES, TAK, TER (A), and BU (A) treatments showed higher water content. The most significant temporal variability in the conductivity-based measurement results was shown by the otherwise well-performing FES treatment, in which the previously favorable values started to deteriorate intensively with the warming of time. Based on the drying intensity of the treatments after precipitation events, the TAK treatment showed the best value, while the FES was among the worse treatments.

In the case of **groundwater retention** values, it is especially important for the plant grower to know the proportion of disposable water content (DV) that can be taken up by the crop. We found a strong relationship between DV, soil binding (KA) ($R = 0.45$ $p = 0.08$) and humus content ($R=0.49$ $p=0.05$), thus confirming the expected relationship described by the literature. The highest total volume percentage moisture content values (DV+HV+GRAV) can be found for the FES, TAK and BU treatments. The best DV value was obtained for the TAK and BU treatments, while the lowest value was obtained for the TER treatment for disposable water (DV), and the overall results (DV+HV+GRAV) were also among the lowest.

Soil resistance data measured in a row and soil moisture data showed a strong correlation ($R=0.43$ $p=0.09$). However, TER treatment with low soil moisture values showed low soil resistance values.

Contrary to our expectations, neither the soil penetrometer data sets ($R=-0.08>$ $p=0.44<$) nor the soil moisture data ($R=0.30$ $p=0.26$;) nor the soil penetrometer data and nor the humus data ($R=0.20$ $p=0.45$) correlated with the **aggregate stability**. However, we found a strong positive relationship between the agrochemical data with nitrate / nitrite ($R=0.64$ $p=0.01$) and carbonated lime content ($R=0.39$ $p=0.14$), while with magnesium content it was negative ($R=-0.50$ $p<0.05$). Of the samples taken from the near-surface zone (F) of erosion interest,

FAC, TER, and TRI were also markedly poorly performed for this parameter expressing soil erosion resistance. The TAK treatment gave good results, but the good results of the MEC treatment were a surprise.

In the **DHA** study, treatments with root mass and organic matter cover (TAK) showed higher values. We found a strong negative relationship between $CaCO_3$ and **FDA** enzyme activity (Spring 2017: p=0.00; R=-0.68; Summer 2017: p=0.00; R=-0.81). In this case, the correlation points to a negative consequence of the surface formation of lime-rich soil-forming rock by erosion processes.

Nextgen metagenomic studies show a rate of over 20% for three treatments examining the amount of pathogenic strains within the community (FAC F, BU F, and TRI F) and extremely low values (less than 5%) were found for FAC A and TAK A. Symbionts generally showed higher amounts in treatments with multiple plant roots. *Rhizophagus irregularis* was identified as the dominant species, which is able to establish mycorrhizal relationships with most agricultural crops and has also been shown to regulate phosphorus uptake by the plant.

Examining the **harvest parameters** indicating the vitality of the crop, we found that the grapes, which showed almost the same must sugar, titratable acid content and pH level, could ripen even with different amounts in the different treatments. TER, BU and TRI, and MEC treatments, respectively, formed a lower-yielding group.

3.3. Tillage intensity comparison - ‘St. George’s Hill’

All three plantations have unstructured sandy soils that can be classified as phylloxera immune. Recently, when examining agrochemical data in any plantation without nutrient replenishment, the most significant differences were observed in the analysis of **copper content**. At near-surface (F) depths, cultivated areas (INT, EXT) contain a larger amount of spray-applied element, especially for EXT treatment, where this low-mobility element slows down to the deeper zone in the absence of vertical disturbance. However, the F area contains a high amount of copper in the deeper zone, certainly the copper content left over from previous cultivation (no plant protection has taken place for more than ten years) has accumulated at this depth and could not be mobilized by the plant spontaneous phytoremediation process.

The **proportion of opportunistic pathogenic fungal genera** identified from rhizosphere samples by culture and PCR methods was higher in the INT plantation than in the EXT (spring: +8.20 summer: +11.18%) and FEL (spring:

+14.54, summer: +9.03%) expectations. appropriately. Based on Shannon's (H', J') diversity values determined at the ethnic level, the **diversity** of fungal communities was the lowest with INT treatment, 59–75% lower than with EXT and FEL treatments.

4. Conclusions and recommendations

Based on the results of our series of studies comparing three different tillage practices: **integrated (I), organic (Ö) and biodynamic (B)** methods, a less mechanically disturbed, less mechanically disturbed biodynamic (B) plantation can be used for grapes compared to the other two treatments. disposable water content (DV) was provided. The same and ecological (Ö) treatment showed better values when examining aggregate stability values compared to more intensive soil disturbance and integrated (I) treatment with certain pesticides (specifically herbicides and insecticides). The value of aggregate stability is related to the soil biology and thus to the "health" condition of the soil, it can be considered as an indicator for detecting and monitoring the changes that take place. In addition, soils with plantations with better aggregate stability values are also more resistant to erosion. The cultivation practice of the integrated (I) treatment (speed trampling damage, tillage methods resulting in compaction) also resulted in significantly higher compaction and soil resistance values, and this was not changed by soil aeration.

Summarizing the above results, the more intense soil disturbance; differences in herbicidal use and the use of different pesticides reduce the ability of the rhizosphere soil to suppress potential pathogens, i.e., soil suppressivity.

As a result of the **soil aeration** we examined for the first time, the values that can be taken up by plants (**DV**) **proved to be higher** without exception, at both A (0–30 cm) and F (30–60 cm) depths. Thus, after soil aeration, the physical-structural composition of the soil presumably improved, even if the results of the soil resistance test showed that the process could not reduce the compaction. Loosening not only improved the available air (oxygen) content, but also increased the moisture content that could be absorbed by the plant. By increasing the air and oxygen content of the soil, integrated (I) and biodynamic (B) treatments with otherwise the highest soil resistance values resulted in clearly increasing values in the amount of stable aggregates. This was presumably due to a higher intensity and degree of microbial activity compared to non-loosened

(NL). However, further durability studies are needed to verify the lasting loosening effect of soil aeration, which was also studied at two depths (A, F).

Our results obtained in a **comparative long-term experiment of row cover and tillage applied in an erosion-affected plantation** confirmed the literature, according to which natural grass (weed flora) can be a significant water competition for grapes as row cover crops. In summary, the best soil cover solution in terms of soil moisture is cover (TAK) and wheat (BU) by providing the highest soil moisture values and uptake water content for the grapes.

However, the poorly performed natural grass cover (TER treatment) **based on the soil moisture values** showed low soil resistance values, certainly due to the fact that the trampling works can be performed here with a smaller number of turns, as no soil disturbance takes place. However, the lower cost level due to the lower number of runs and the better (lower) compaction values overshadow the arguments against rejecting this treatment on plantations exposed to erosion. In years or in areas where the moisture content available to the crop is the most critical parameter, it is contraindicated to cover at least all row spacing in this way. However, when the water competition from this treatment is tolerable, the farmer can take advantage of the benefits described above and apply them to his plantation.

In the study of aggregate stability values, among the samples taken from the near-surface zone (F) from the point of view of erosion, Phacelia (FAC), area-specific weed flora (TER) and triticale (TRI) were also markedly poorly performed in this parameter expressing soil erosion resistance, while the TAK treatment gave good results. This can be important if the treatments are broken for some reason and barren soils are even more exposed to erosion.

Nextgen metagenomic studies show a rate of over 20% for three treatments examining the amount of pathogenic strains within the community (FAC F, BU F, and TRI F) and extremely low values (less than 5%) were found for FAC A and TAK A. Such a survey and this result may help the farmer to consider the degree of risk involved in using root disturbance (mechanical tillage in soil zones with significant grape roots) and thus expose the grapes to attack by underground pathogenic fungi. The most significant soil disturbance occurs in the case of temporary mulch (BU) and triticale (TRI) treatments, so the result is a higher pathogen ratio than these, which is warning and to be taken into account.

Study of plantations for comparison of tillage intensity

The values measured for the copper content of plantation soils exceed the toxic level set by the EU (50 mg/kg) in only one case for EXT F, but the value set by the Netherlands (36 mg/kg) in all cases except FEL F. At the same time, it can be stated that if we compare our results with other studies on the soils of European vineyards, none of the values is great. Based on our results obtained by examining the fungal communities, it can be said that the more intense soil disturbance influences the suppressivity of the rhizosphere of vineyards characterized by the above abiotic conditions, the more intense disturbance reduces it. Thus, in addition to obvious economic considerations for the producer in favor of reducing cultivation practices involving relatively high energy-intensive soil disturbance, another aspect to be considered is the potential impact on the above plantation condition.

5. New scientific results

1. The integrated cultivation method reduces ($p < 0.05$) the aggregate stability and the percentage of stable macro-aggregates compared to the organic and the biodynamic cultivations.
2. The soil resistance data measured between rows and the soil moisture data were positively correlated ($R=0.43$ $p=0.09$), however, the soil of the natural grass cover treatment with lower soil resistance values with lower number of turns, had low soil moisture values due to the vegetation cover (drying coefficient: 0.0097).
3. For the first time in Hungary the grape rhizosphere fungal community were characterized, with nextgen shotgun metagenomic methods, beside the traditional agrophysical, chemical and biological methods, in connection with the tillage and mulching methods applied in the vineyards.
4. Next generation shotgun metagenomic and culture mycological studies have also shown that more intense soil disturbance of the vineyard reduces soil suppressivity and increases the proportion of pathogenic fungal species within the community.
5. Our study is the first on the effect of soil aeration on the amount of disposable water content in vineyards. As a result of the treatment it increased at both 0-30 cm and 30-60 cm depths, so the soil could provide more moisture to the plant.
6. Under standardized basic conditions (same: age of vine, rootstock and noble variety, cultivation method, pruning method, bud load, canopy management and harvest time) are affected by different soil cover methods like TER, MEC, BU, TRI less than average, while FAC, PILL, FES, and TAK treatments were above the average in yield.
7. The symbiont fungus *Rhizophagus irregularis* has been detected in the rhizosphere of all treatments as the dominant in the vineyard at Badacsony hill. It appeared with greater abundance in the erosion-exposed plantation if legumes (PILL), cereal cover crops (BU, TRI) and mechanical cultivation (MEC) were applied.

6. List of publications in the topic of the dissertation

Articles published in peer-reviewed scientific journals in Hungarian

1) Kovács, B; Sebők, F; Dobolyi, Cs; Nagy, PI; Kocsis, L (2016): **Talajművelési eljárások hatása a szőlő rizoszféra gomba és fonálféreg közösségeire**. Borászati füzetek 2016:6 pp. 28-32., 5 p.
2) Kovács, B; Kocsis, L; Szabó, P; Szakálas, J; Seres, A, Nagy, PI (2020): **Extenzív, intenzív és felhagyott ültetvények talajkezelési gyakorlatainak hatása a fonálféreg denzitásra szőlőültetvények rizoszférájában**. Talajvédelem, Különszám: Talajhasználat – funkcióképesség: Talajtani Vándorgyűlés 2018 pp. 133-143., 11 p.

Articles published in peer-reviewed scientific journals in foreign language

1) Kovács, B; Varga, P; Májer, J; Németh, Cs; Szabó P; Kocsis, L (2018): **Sustainable soil management in the Badacsony Wine District.** Ecocycles 4: 2 pp. 80-84., 5 p.
2) Kovács, B; Dobolyi, Cs; Sebők, F; Kocsis, L, Tóth, Z (2020): **Effect of vineyard floor management on seasonal changes of cultivable fungal diversity in the rhizosphere.** Agriculture, Basel 10: 11 Paper: 534, 12 p. (*Q2, IF: 2,072*)

Papers published in full in a conference paper

1) Kovács, B; Kocsis, L; Varga, P; Májer, J (2019): **How cover crops and mulching effect on soil biological and physical parameters.** In: Bihari, E; Molnár, D; Szikszai-Németh, K (szerk.) Tavaszi Szél - Spring Wind 2019. Tanulmánykötet I. Budapest. Doktoranduszok Országos Szövetsége (2020) 643: 61-65.

Conferences, abstracts, posters

1) Kovács, B; Kocsis, L; Seres, A; Szakálas, J; Nagy, P (2017): **Effects of cultivation methods on nematode communities in grape rhizosphere.** In: Clement, Christophe Plant BioProtech : Book of Abstracts, Reims, Franciaország : Université de Reims, (2017) p. 112
2) Kovács, B (2017): **Ökológiai szőlőültetvények egészséges talajai.** Boregyetemek és Borrégiók Találkozója - Nemzetközi Bortudományi Konferencia, Előadás

3) Kovács, B; Kocsis, L; Szabó, P; Szakálas, J; Seres, A; Nagy, PI (2018): **Az egyes művelési eljárások hatása a fonálféreg denzitásra szőlőültevények rizoszférájában.** In: Bakacsi, Zs; Kovács, Zs; Koós, S (szerk.) Talajtani Vándorgyűlés: Absztrakt és program füzet: Talajhasználat – funkcióképesség, Magyar Talajtani Társaság, (2018) pp. 56-57.
4) Kovács, B (2019): **Wine cultural landscape management in a traditional wine region of Hungary.** In: Ribeiro, D; Gabrovec, M; Gasperic, P; Gersic, M; Koderman, M (szerk.) IGU Thematic Conference "Transformation of Traditional Cultural Landscapes": Abstract and Guide Book, Ljubljana, Szlovénia: Zalozba ZRC (2019) 112 p.p. 84
5) Kovács, B; Varga, P; Májer, J; Kocsis, L (2019): **The biological and physical effects of tillage cover crops and mulching on an erosion exposed vineyard.** In: Németh, K. (szerk.) Tavaszi Szél Konferencia 2019: Nemzetközi Multidiszciplináris Konferencia: Absztraktkötet, Budapest, Magyarország: Doktoranduszok Országos Szövetsége (2019) 747 p. pp. 66-66., 1 p.
6) Kovács, B; Pacsai, B; Stankovics, P; Márton, B; Szabó, P; Kocsis, L (2020): **Szenzoros talajnedvesség és talajközeli hőmérséklet felmérés különböző, talajvédelmi célból alkalmazott takarónövényzettel és mulcstakaróval rendelkező szőlőültetvényben.** In: Barna, B. J.; Kovács, P.; Molnár, D.; Pató, V. L. (szerk.) XXIII. Tavaszi Szél Konferencia Absztrakt Kötet: "MI és a tudomány jövője", Budapest, Magyarország: Doktoranduszok Országos Szövetsége (2020) p. 46.
7) Kovács, B; Pacsai, B; Kocsis, L (2020): **Monitoring of a vineyard soil moisture and ground-zone temperature by automatic sensors: - GROW Observatory: a European database building by citizens.** - In: 2nd Annual Meeting. INTEGRAPE 2020. Multi-omics data integration for genotype-phenotype association : Book of Abstracts (2020). p. 33.
8) Kovács, B (2021): **Művelési eljárások hatásai a szőlőültetvények talajegészség-állapotára.** In: Szabó, Péter (szerk.) Szőlő szaporítóanyag-előállítási tudományos konferencia, Budapest, Magyarország: Doktoranduszok Országos Szövetsége (2021) p. 39.