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Mulching in grape plantations

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Summary: In continuous studies regarding the conservation of the advantageous condition of the soil structure, the highland plantations that are surrounded by living waters have major importance where the erosion of the soil, nutrients and chemicals endangers the quality of the water and the living world of the waters. At the same time the extreme weather and dry summers of the past years have made it important to look for soil cultivation solutions and technologies that are capable of decreasing the evaporation of the soil, for enhanced conservation of soil moisture and to improve the soil structure that is required for the growth of healthy roots. In our experiment we have studied soil mulching with organic plant residue, by sods and the effect of the mechanical cultivation on the soil and on the grape through two growing seasons. From the studied treatments, the mulching with organic plant wastage showed the most efficient results from the point of view of the nutrient distribution in the grape and yield. It also had a positive effect on the soil structure and humidity.

Key words: soil covering with organic plant residue, mechanical cultivation, mulching by sods, soil moisture, soil structure, nutrient distribution

Introduction

In the cultivation systems of environment-oriented grape growing, the protection of the soil and living water including protection against erosion is a major task. But besides the protection against erosion, at habitats that are ecologically dry, like the highlands of Lake Balaton, water saving is also an essential aspect when choosing a definite technology. Besides the continuous studies regarding the conservation of the advantageous condition of the soil structure, the extreme weather of the past years has made it important to look for soil cultivation solutions and technologies that are capable of enhanced conservation of soil humidity, and to improve the soil structure required for the growth of healthy roots. However it has become necessary to develop alternative cultivation and mulching technologies that fulfil the requirements of integrated growing.

Considering these aspects cultivation methods must be applied that are also compatible to the integrated growing technology to fulfil the required demands. This could be mulching with organic plant residue, soil covering by sods, and with some restrictions, mechanical cultivation.

In the international and national literature, most of the authors recommend the usage of agricultural and communal residue for mulching in grape growing areas where the annual precipitation does not reach the level of 700–800 mm. These materials improve the organic matter content of soils, decrease the danger of erosion and keep the moisture in the soil for the cultivated plant (*Basler,* 1992; *Boller* et. al., 1998; *Varga,* 1994). Similar to this in areas where the annual precipitation does not reach the level of 250 mm or the tilth depth is low, other possibilities must be found to keep the moisture in the soil at the conditions of conventional mechanical cultivation. This can be, for example, covering the soil with straw, bark, foil or with different agricultural organic plant wastage. Many studies deal with the advantages and possible disadvantages of these methods. (*Bauer*, 1992; *Link*; 1998; *Zanathy*, 1998; *Szabó* et al. 2001). According to these for example the experiments in South-Australia showed 34% increase in the soil moisture content and 46% increase in the amount of grape production by total covering of the soil (*Buckerfield* & *Webster*, 1996).

In Hungary *Varga* (1994) has compared soil covering with straw and saw-dust with mechanical cultivation; the moisture preserving effect of mulching during the hot and critical summer months was proven. His experimental results certify that before spreading out another amount of straw, a deep tillage is advisable. The straw covering effectively decreases the evaporation of the soil, so it can also play a serious role in keeping the natural moisture in the soil (*Varga*, 1996, 1997). The time for the most efficient spreading of the straw is autumn, while the importance of the method is mainly to keep the winter moisture in the soil. It can be dangerous, because, like the dry grass it is also highly flammable and the power machines can slip on the dry straw layer (*Nagy*, 1986 b). The increase of the different furrow-weed in the straw layer plays a part in decreasing the fire hazard (*Varga*, 1996, 1997). The covering straw layer thins down slowly and the straw needs to be replaced every three years (*Varga*, 1996, 1997). If, out of the many positive impacts of covering the soil with organic plant refuse, we highlight its effects on structure and moisture, *Némethy* &

Németh (2002); *Májer & Varga* (2003); *Varga & Májer* (2004), measuring the soil penetration resistance and moisture with sensing head, found the method of covering the soil (with organic plant refuse) clearly more favourable than the method of sods and mechanical cultivation.

In his book *Bauer* (2002) writes particularly about the possibility of mulching with agricultural organic plant wastage in grape plantations, also mentioning the possibilities of mechanization. *Májer* (1999) in his study writes particularly about the notability of the soil covering at the highlands of Lake Balaton. According to Swiss experience, the great mass of reed residue which accumulates in national park areas could be used for mulching. We can expect other phytopathological and zoological effects of mulching with organic plant material too. For example straw mulch was shown to reduce plant pathogens in integrated and organic orchards (*Nagy* et al., 2006; *Holb*, 2006). Wood chips modify the micro climate and produce allelopathic substances that affect the weed and insect population in vegetables and fruits (*Masiunas*, 1998). Researchers have studied the allelopathic effects of mulching in grape rows too (*Mikulás* et al., 1989, 1990, 1992). According to Hungarian research, the *Digitaria sanguinalis* – due to it's allelophatic effect – is a favourable species for mulching in grape rows (*Mikulás* et al., 1991).

In grape plantations on impermeable soil, the application of straw and wood chips as mulch ensured remarkably greater humidity for the rootage of the grapes in the soil compared to the mechanical cultivation, especially in the deeper soil layers (*Várnai* et al., 1998). On sand by applying straw mulching 3.5–5.0 V % of plus soil moisture, soil penetration resistance can be decreased by 60% in proportion to the soil structure compared with covering plants and cultivation by mechanical devices (*Némethy*, 2004).

In areas where the annual precipitation is 500-520 mm, sod covering is suggested for only the strongly growing grapes. Mulching can be appropriate for areas where the joint amount of annual precipitation and occasional watering is about 800-1000 mm. For example *Moser*, (1966) suggests mulching only on areas where the annual precipitation reaches the 800 mm level, or the missing amount can be compensated by watering. In the past few years, the annual precipitation was not sufficient for mulching between grape rows in Hungary, although in some areas it can be workable by the application of certain methods. *Bauer* et al., (1992) suggests total mulching for all of the rows where the amount of the average annual precipitation is over 250–300 mm during the growing season. In areas where this level is lower it is worth mulching in every second row and in the rest to grow periodical plants, and cover them with straw or cultivate mechanically.

In several studies the nitrogen adsorbing effect of mulching is also reported. Because of the covering plant, the nitrate content of the soil is controlled through the whole year and stays at a quite low level, and this decreases the danger of nitrogen wash-out (*Zanathy*, 1998). In the plantations that are mechanically cultivated, because of the frequent actions that is caused by the more intensive decomposition of the humus content, a bigger amount of nitrate is stored and then washed-out from the soil. However the grass covering can decrease the grape yield too according to it's dehydrating effect, beyond the fact that grass is a nutrient competitor for the grape. Hungarian research (*Lisicza* 1981) reports the yield decreasing effect of grass covering.

In dry areas the planting of red fescue (*Festuca rubra*), meadow-grass (*Poa pratensis*), sheep's fescue (*F. ovina*), thin-grass (*P. trivialis*), dog's-tail grass species (*Cynosurus cristatus*) are recommended and these can be mixed with white clover (*Trifolium repens*) too. In the area of Badacsony where the slope of the land is 12–16% *Oláh & Czinkóczki*, (1996) found the *Festuca pseudovina* and the *Festuca ovina var. Capillata* species the most suitable for covering the soil in grape plantations, because these plants have the least green mass and dried foliage, and so are less dangerous competitors for the grapes in the race for utrients. In the studies of *Diófási* et al., (1994) they examined several grass species and from the point of view of the soil moisture content, the 30–30% mixture of *Festuca rub*ra and *Poa pratensis* seemed to be the most resistant to dryness.

Several authors studied particularly the erosion decreasing effect of mulching by sods in sloping areas (*Moser*, 1966, *Csizmaziané*, 1984, *Óvári*, (1998). *Nagy*, (1986 b), they write about covering the soil of the grape plantations in hilly and mountain areas by mulch. The most important advantage of this method is that it increases the aeration degree and decreases the damage caused by the erosion. But it also has a disadvantage, namely the water demand of the area increases. In some cases the water absorption of the *Festuca* species decreased the vitality of the grape (*Morlat* et al., 1981). If the amount of the moisture is low, the soil covering by sods can be harmful to the grape, so the final solution can only be a compromise between the prevention of erosional damage and yield loss.

Hungarian researchers report experiments with other covering plants. By testing rye, the natural weed flora and the *Digitaria sanguinalis* as covering plants between the rows on sand, the most advantageous soil moisture was measured in rows covered with Digitaria, second were the weeds, and third was the moisture content of the soil covered with rye (*Balogh* et al., 1997).

A specially important task is to decrease or cease the mechanical cultivation in highland plantations next to living waters, such as the grape plantations of the highlands of lake Balaton in Hungary where a significant part is situated in a national park. In these areas the wash-out of the soil, the nutrients and chemicals endanger the quality of the water and the living world of the lake. At the same time, mulching between the rows – that fulfils the requirements of the integrated plant cultivation – can cause moisture withdrawal symptoms. Because of the above mentioned reasons, the covering of these areas with environment friendly organic materials which retain the moisture in the soil is a primary task. Considering this question from another point of view, in the national park, after the compulsory mowing of the coast, 8000 tons of unusable cut organic plant residue consisting of reeds, bulrushes and Solidago is available that must be stored or annihilated. These organic materials are suitable for using as mulch in vine plantations. The technological solutions (having the covering plant, spreading the natural organic covering material) may provide replacement for soil cultivation with mechanical devices, may retain the moisture content of the soil, may decrease its compactness, and increase the plants ability to absorb nutrients from the soil. At the same time the physical and chemical load on the natural and biological environment may be decreased.

After the recognition of the practical problem and the local conditions, the HIAE and the RIVAE in Badacsony set a target to analyse the effect of covering the soil with organic plant residue, to analyse the effects of mulching and mechanical cultivation on the abundance of nutrients, the yield and the moisture content and compactness of the soil in the case of vines.

Materials and methods

In the year 2000 the experiment was launched at the no.2 vineyard of the Institute in Badacsony regarding:

- a_1) plant covering (mulching)
- a_2) covering with organic plant residue (waste reed, mixture of reed, bulrushes and Solidago)
- a_3) mechanical cultivation between the rows

Each treatment was applied on an area of three complete rows, involving an area of 1020 m2 for each treatment. The experimental field was Szürkebarát type plants with 2x1 m space between the rows and between the plants. The field was planted in 1995 and it's cultivation was shield type. During the experiment, the constant plant covering was formed by leaving the weed flora that resisted mowing. Cultivators and disc harrows were used for mechanical cultivation of the space between the rows. The organic plant wastage material was spread totally on the field (under the rows too), the amount was 5 kg/m^2. The formed covering layer has thinned down since then, the expected effect was not realised. Renewal of the covering layer become necessary. Before the spreading of the new covering layer, the old layer was worked into the soil by a cultivator (27.03.2003) then the new covering layer was spread (01.04.2003.). On the basis of our experience from the former tests, we determined the amount of the covering material at the higher level of 10 kg/m2. The wastage reed for the covering was provided by the Balaton National Park. A total covering was applied, involving the covering of the space between the rows and under the plants too. Before the spreading of the covering material, the soil was rotated with a cultivator and cleared from weed. The bales of the covering material were spread by a HAMMERSCHMIED RST VL2 type bale spreading machine or manually. The capacity of the spreading was 0.24–0.30 hectare/shift. After the settlement of the covering, a 8–12 cm thick continuous covering layer formed on the covered plantation and after that there were no further cultivation applied during the growing-season.

In the experiments we solved the cultivation of the area under the rows by chemical weed control in the mechanically cultivated field. The green works, the plant protection and the cultivation were ensured by fitting them into the grape growing system of the grape yard, considering the higher requirements of the characters of the experiment. In both of the experimental years the ordinary annual 50 kg/hectare N fertilization was applied in spring (05.16.2003.), (05.17. 2004), by spreading it onto the surface consistently.

To enhance the effect of the dependability of the „information coming from the plant", we have marked 4 parcels with 4 intercolumniations in each. This allowed us to evaluate the results by using the analysis of variance.

In spring, after pruning the areas as a whole field, we set the final bud load in the marked parcels. We tried to reach uniformly 7 bud/m^2 load in both years of the experiment during the treatments.

During the growing-season, for the easier characterization of the occasional changes that can take place in the soil or in the plant affected by the treatments, we have collected soil and leaf samples at blooming time (30.05.2003.); (13.06.2004.), at maturation (27.08.2003.); (28.09.2004.) and from the treated parcels of the experiment. During the two growing-seasons, we have completed bonitations and observations on the plant stocks. During the experiments, we measured the moisture content of the soil at 0–30 cm and 30–60 cm depths and soil resistance characterizing the soil compaction by three repetitions, six times in 2003 and five times in 2004. We have averaged the two results of the moisture content of the soil in 0–30 cm and 30–60 cm depths to define it with one number for easier handling. For the measurements a Penetronic electronic test-needle and a Psion data collecting unit were used.

In autumn we determined the grape harvest parameters on both fields by testing the grape harvest (amount of clusters, sugar level of the grape-juice, the titrateable acid content of the grape-juice). From the samples resulting from the treatments, while bearing the average of the repetitions in mind, wine was made by microvinification.

Results

The effects of different soil cultivation on the whole organic material , on the mineral nitrogen content of the soil and on the nutrient content of the leaves.

We have measured higher „humus-contents" (whole organic material content) in the soil in the soil cultivation experiments at the fields that were covered with organic plant residue or with grass at blooming and at maturation too in both of the test years in both measured depths, than in the soil that was mechanically cultivated (*Figures 1 and 3*). The higher level of humus in the soils that were covered with organic plant residue and with mulching is partly because of the presence of the organic material that was worked into the soil before, and because of the presence of the decomposing root residues in the case of mulching. This difference was confirmed statistically too.

A significantly higher level of mineral nitrogen (nitrite+nitrate) content was sensed in the mechanically cultivated parcels in both test years, and in both test depths than in the parcels that were covered with organic plant residue or mulching (*Figures 2 and 4*). The higher level of nitrogen content in the mechanically cultivated parcels was partly because the harmful pentosan effect did not occur, but at the same time the lower nitrogen level in both measuring depths also shows the pentosan effect and the presumable demand of the plants for additional N in the organic plant residue covered and mulching too. The nitrogen fertilizer that was spread both years on the surface of the fields covered by organic plant residue and mulching to help the decomposition of the organic material that was formerly buried in the soil was not enough. Decomposing root residues were found in the field covered by mulching, the mineralisation of which requires nitrogen, but the N competition of the plant cover can not be neglected either.

According to the leaf analysis tests, the amount of nitrogen in the soil was optimal at blooming and maturation too in both tested years. The highest values were always measured in mechanically cultivated parcels. The phosphorus and potassium content was generally at the optimum level with few exceptions. At maturation a mild phosphorus malnutrition could always be measured.

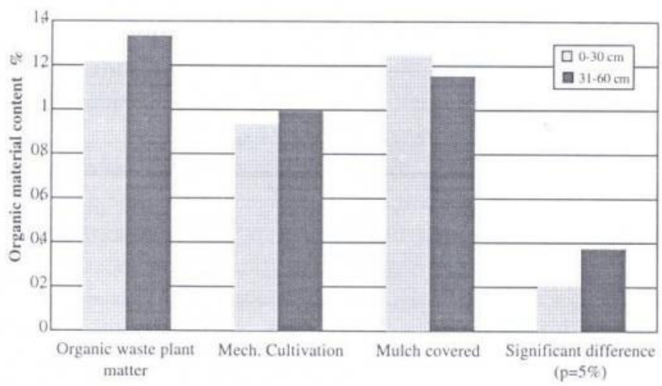

Figure 1. Organic material content of the soil samples collected during flowering in the soil cultivation experiment (Badacsony, 2003)

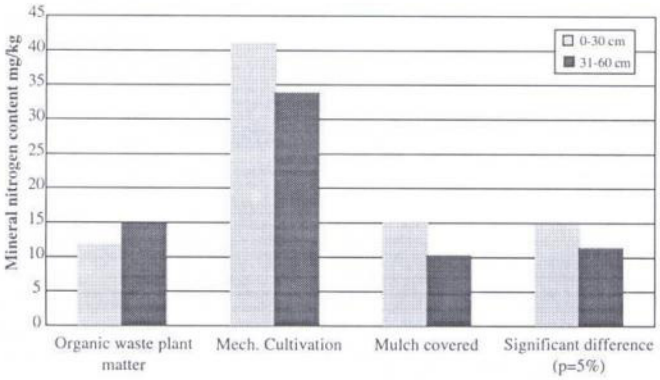

Figure 2. Mineral nitrogen content of the soil samples collected during flowering in the soil cultivation experiment (Badacsony, 2003)

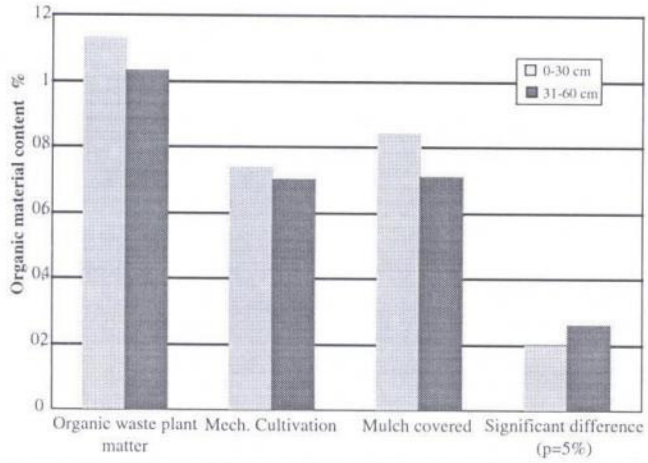

Figure 3. Organic material content of the soil samples collected during flowering in the soil cultivation experiment (Badacsony, 2004)

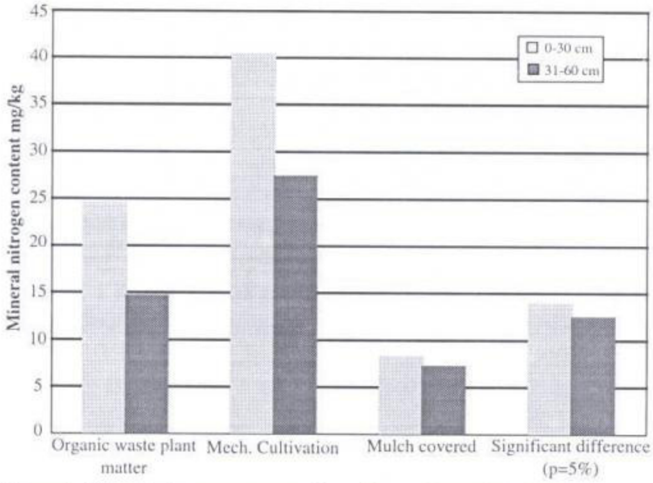

Figure 4. Mineral nitrogen content of the soil samples collected during flowering in the renewal of the covering-strata experiment (Badacsony, 2004)

The effects of the soil cultivation methods on the soil moisture content and on the soil compactness

In the year 2003 the *Figures 5 and 6*, and in the year 2004 the *Figures 7 and 8* show the average results of the soil characteristic measurements between the rows on the parcels that were covered with organic plant residue, natural weed and were mechanically cultivated down to 60 cm depth.

After the evaluation of the experiences of the two years of the experiment, the summarized main establishments of the soil covering tests are the followings:

– The most beneficial soil moisture content and the lowest soil resistance were always measured during the active vegetation period that lasted from April to September in the fields that were covered with organic plant residue material (*Figures 5 and 7*) from the studied soil covering methods and plantations. Compared to the traditional mechanically cultivated parcel that was the control, during summer time the moisture content of the parcels that were covered with organic material was consistently 7–15 V% higher in the year 2003 than the moisture content of the mechanically cultivated soil. These values meant keeping 46-86% more moisture in the soil for the grapes. In the year 2004 which was more rainy, only 4–6V% extra soil moisture content was measured in the rows that were covered with organic plant residue that meant 20–31% more moisture for the grapes. The retention of the moisture content was especially apparent in the upper 30 cm layer of the soil where the extra moisture content in the summer of 2003 even reached plus 15 V%.

- During the same period in the rows mulched with sods the moisture content of the soil was 3.4–7 V% lower than the traditionally mechanically cultivated row, during the whole vegetation period. These values meant a decrease of 33–49% of moisture in the soil from the vines that is clearly attributable to the absorbing and evaporating effect of the covering plants.
- At the end of the vegetation period, as a result of the September rains the differences between the moisture contents of the different covering methods became lower, but even still the value in the rows that were covered with plant residue material was 5–6 V% higher. In the parcels where we did not apply soil rotating with a cultivator before spreading the covering material, the moisture content of the soil was usually 1–3 V% lower than in the areas that were newly formed (where the soil was rotated by a cultivator). This is because the formerly rotated soil could retain more water from the winter and spring rains.
- Analysing the soil resistance (penetration) results that characterize soil compaction *(Figures 6 and 8)* it can be stated that in summer time the lowest values were measured in the rows where the soil was covered with organic plant residue. The soil resistance values in 2003 even in the most dry periods did not reach 210 N/cm^2, while in the control parcel that was mechanically cultivated the maximum value reached was 420 N/cm^2. The highest value was measured in the rows that were covered with living grass, in these rows the soil resistance reached 820 N/cm^2 in the same period of time. In the rows that were covered with plants (mulching) the measured results were 260–500 N/cm^2 higher during the whole year, compared to the mechanically cultivated rows, but in the parcels that were covered with reed, bulrushes and Solidago, the soil compaction characteristics were 80–220 N/cm^2 lower or even more favourable compared to the same parameters of the mechanically cultivated rows.
- According to our experience, the advantageous effects of the spread covering material can be maintained for two years. After that the covering material thins down, starts to humificate and the weeds (mostly bearbind) start to grow across the covering layer in a greater number. Because of the above mentioned reasons, after two years in autumn the covering material should be dug into the soil with a cultivator that also ensures the aeration and more favourable winter moisture absorption of the soil. After this a new, fresh covering material needs to be spread. According to our experience, it is better if the covering material contains reed residues in a greater amount, because the decomposition of these is much slower than the mixtures of reed, bulrush and Solidago. As an alternative solution, the renewal of the two-year-old covering layer can be spread with a new layer of covering material. In this case, the amount of the new covering material should be 5–10 kg/m^2 depending on the condition (thickness, uniformity, weediness) of the existing layer.

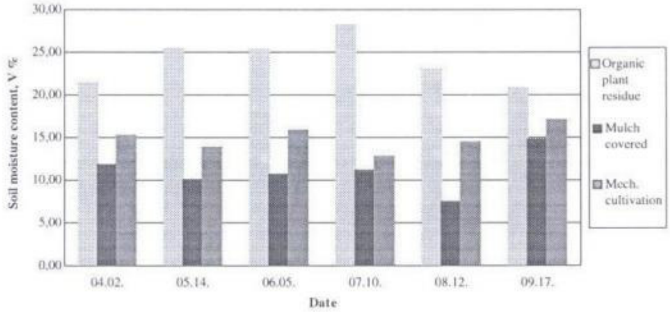

Figure 5. Soil moisture contents, under different cover crop (Badacsony, 2003)

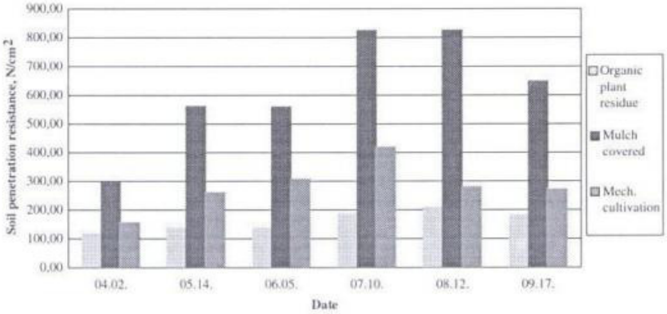

Figure 6. Soil penetration resistance, under different cover crop (Badacsony, 2003

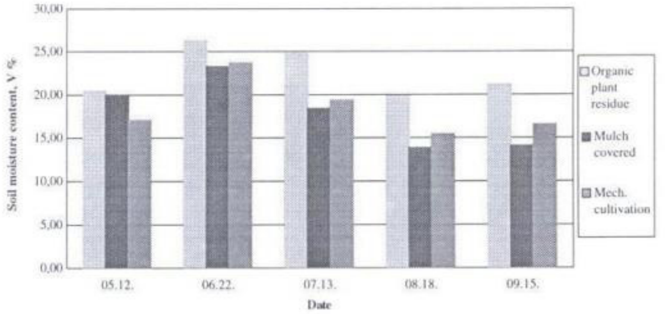

Figure 7. Soil moisture contents, under different cover crop (Badacsony, 2004)

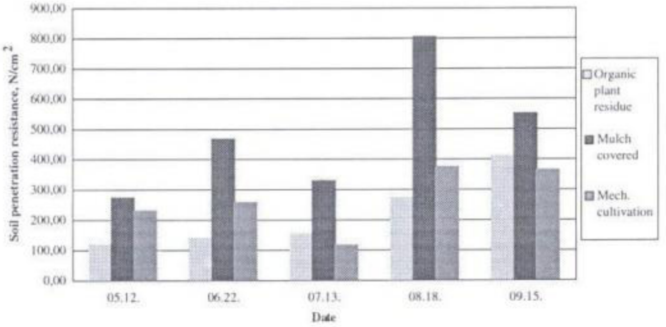

Figure 8. Soil penetration resistance, under different cover crop (Badacsony, 2004)

Table 1. Effect of cultivation method on the harvest results in 2003 (Badacsony, 2nd field)

Treatment	Date of harvest	Must degree (Klo)	Titatable acid content (g/l)	Quantity of crop (kg/m²)
Organic plant residue	08.29. 2003.	18.60	6.57	1.99
Mech. cultivation	08.29. 2003.	20.60	5.87	1.47
mulch covered	08.29. 2003.	17.90	5.40	1.18
significant difference (p=5%)		3.44	0.47	0.24

Table 2. Effect of cultivation method on the harvest results in 2004 (Badacsony, 2nd field)

Treatment	Date of harvest	Must degree (Klo)	Titatable acid content (g/l)	Quantity of crop (kg/m²)
Organic plant residue	09.28. 2004.	18.40	9.49	1.32
Mech. cultivation	09.28. 2004.	19.73	10.57	0.65
mulch covered	09.28. 2004.	20.40	9.88	0.60
significant difference (p=5%)		0.56	1.31	0.23

The effects of the soil cultivation methods on the results of the grape harvest

The average results of the grape harvests of the tested two years reveal that on the parcels that were covered with organic plant residue, the yield increased by 69.23% compared to the parcels that were mechanically cultivated (*Tables 1 and 2*). But on the areas that were covered with mulching an average 13.71% decrease in the yield was detected in the two years compared to the parcels that were mechanically cultivated. In 2004 the difference between the yields from the mechanically cultivated parcels and fields that were planted with mulching was lower than a year before, because the moisture supply was better in 2004. These differences can also be proved by statistical methods. In 2003 the weather was drier and the differences between the measurements were bigger than in 2004 when the weather conditions were better. Increase in the acid content was only experienced in 2003 and then the value was higher in the covered soil. This effect can be evaluated as extremely advantageous, considering that the weather was mild that year. There were no remarkable differences in the sugar levels of the grape juices.

Conclusion

According to the results of our soil physical analysis it can be determined that the covering of the soil with organic plant residue is very advantageous to the moisture content and compaction of the soil, and that the worst value was measured in the parcels with mulch.

The total organic material content of the soil was increased in both tested years at the covering with organic residue and that with mulch. This was caused by the effect of the decomposing organic material and root residues. At the same time the mineral nitrogen content of the soil decreased compared to the soils that were mechanically cultivated. This fact must be kept in mind when realising the annual tasks of growing technology. The higher mineral nitrogen contents of the mechanical cultivation handlings show that there were no harmful pentosan effect on this parcels. But the measured lower nitrogen level of the organic plant residue and mulch covered fields in both measured depths presumes the pentosan effect and the extra demand of the plants for N.

During the examination of the different soil cultivation methods it was established that in the case of the covered and mulched treatments, the decomposition of the organic material (covering material and root residues) requires nitrogen.

In the two years of the examination, it transpired that the treatment of covering the soil with organic plant material had the most favourable effect on the quality and quantity of the yield. The effect on the quantity was the increase in the number of bunches and the effect on the quality was the positive effect on the acid content of the grape juice. These positive effects are more important in dry years. Our conclusions are in accordance with the results of the same tests of *Buckerfield* & *Webster* (1996). And our conclusions about the negative effect of mulching on the bunches in a dry year are in accordance with the statements of *Lisicza* (1981) and *Bauer* (1992).

According to our experience the organic plant material spread at a thickness of 5-10 kg/m2 can be used for two years and after that it must be dug into the soil with a cultivator and renewed.

Based on our results we think that the examined organic plant residue materials formed in the Balaton National Park are also ready for industrial use as mulch in grape plantations, because the spreading of the material on the field can be mechanized.

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