CHANGES IN SOIL PHYSICAL PARAMETERS AS A RESULT OF SOIL AERATION

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Abstract. *Among soil degradation processes, the physical degradation of soils (deterioration of soil structure and compaction) is one of the most widespread and largest worldwide damaging process. In Hungary, 34.8% of soils are affected by soil compaction. Soil compaction is a problem in many fruit plantations. Phisical soil degradation can be caused by natural factors, such as heavy rain. Most often, however, the machines of agronomy, irrigation, plant protection, mowing, harvesting. In compacted soil, precipitation, irrigation water, and nutrient supply are not utilized to the appropriate extent. Physical degradation of soil involves the destruction of soil structure, dispersion of soil particles, sealing of pores, compression and increasing density, consolidation, compaction and reduced root penetration, low infiltration, waterlogging and runoff, and accelerated erosion. To maintain the physical condition of the soil, different methods of agronomy are used, such as the use of soil loosening devices and the planting of mulching plants. Most recently, soil aeration is used. In the present experiment, the technology was applied in cherry and plum orchards in Tápiószele to evaluate the efficiency of soil aeration. Soil aeration, mechanical soil loosening by the introduction of compressed air. The process involves injecting compressed air at a pressure of 12 bar for a few seconds at a depth of 90 cm into the soil. At depth, this creates a kind of micro explosion. This causes the previously compacted soil to crack, increasing its pore volume and making it permeable to water and nutrients, which can then penetrate to the lower layers of the root zone. The present experiment aims to investigate the physical parameters of the soil. The experiments started with soil sampling in early 2024. We are measured soil resistivity and soil moisture with a Daróczi-Lelkes penetronik instrument in four replicates. Soil samples were taken from 0-10 cm, 10-30 cm and 30-60 cm depths as controls for soil moisture and soil resistivity. In the laboratory, we determined the gold binding number and the leachable fraction of the soil.*

Keywords: *soil degradation, soil compaction, soil aeration, fruit plantation*

INTRODUCTION

Soil degradation is a serious problem in Europe and around the world. Every year, nearly 70 to 80 billion hectares of land are lost, 20 times more than the rate at which land is being restored. In other words, in 50-60 years, land that can be used for production will be virtually gone (https 1). Human activities such as industrial activity, industrial and urban expansion, inappropriate agricultural and forestry practices and tourism play a major role in soil degradation. The consequence of these externalities is a reduction in soil buffering capacity, biodiversity, fertility and carbon content. The impact of pollutants in the soil will increase and the dynamics of the gas and nutrient cycles will change (https 2).

Similar factors threaten soil conditions in Hungary. We are constantly forced to provide porosity to our soils by artificial means (ploughing, rotation). Soil degradation can be caused by machines that go over the land up to 6 to 8 times during the growing season, compacting the soil. The soil loses its healthy structure and biological value. Intense mechanisation has led to the emergence of more and more heavy machinery, which overloads our soils, changing the soil's ability to absorb and retain water. The adverse effects of soil degradation come later, but come a rain and the soil structure is back to a sludgy, compacted, hard soil (https 3).

Soil degradation processes vary between agricultural sectors. In fruit growing technology, the following soil degradation processes are encountered. Soil compaction also causes many problems in plantations because of the constant compaction of the soil by the machinery working between the rows, rainfall and possible irrigation. Its structure changes, its bulk density increases, sometimes exceeding 1.6 - 1.8 g/cm^3, the pore volume of the soil drops below 40%, the air-water ratio shifts unfavourably. In such cases, nutrient supply and precipitation cannot be properly utilised in the soil. This problem is not only present in older plantations but can also be a problem in newly planted orchards. The soil is prepared at the time of establishment (ploughing, disking) and later weed control is achieved by spraying with herbicides or by seeding the area with a greening mixture and mowing. But after these activities, soil loosening is not usually carried out, so the soil can quickly become compacted, the yield of trees can be reduced and their life span shortened. Other problems caused by compaction include the inability of the soil to absorb water after heavy rainfall, which increases the risk of inland flooding in lowland areas (the lowlands) and soil loss due to erosion (Ilyés, 2018).

Soil loosening can be done by using different cultivation tools (soil loosener, cultivator), by planting soil mulching plants in the soil strips or by using a newer, more modern technology called soil aeration. The process of soil aeration and the aeration status of the soil not only influence the water and nutrient levels in the soil, but also have a decisive impact on fertility, compaction and soil structure. Soil aeration increases oxygen concentrations, which will be beneficial for plant roots and microbial populations, and reduces carbon dioxide concentrations (Ben-Noah & Friedman, 2018). It reduces soil compaction, thereby bringing soil structure closer to its original state, as pores in healthy soils are wide and can easily absorb rainwater. The smaller pores inside the soil crumbs, in turn, sponge water laterally from the large pores, making room for the next amount of precipitation and air. This maintains a healthy biological activity, the simultaneous presence of water and air, creating an ideal environment for crop growth (https 3). This process also helps the development of fruit trees in spring, as after winter, the trees begin to prepare for the growing season. During this time, water usage and nutrient absorption increase, which lasts from bud break to the end of the first shoot growth - until early June (Cselőtei, 1993). Thus, it can be stated that soil moisture content and biology largely depend on soil structure and compaction.

MATERIAL AND METHODS

In the current experimental setup, we sought to answer how soil aeration affects the physical parameters of the soil, soil moisture, and soil compaction. The increasing popularity of this procedure in Europe is due to its numerous beneficial effects that can facilitate the work of farmers (Glinski et al., 2000).

The study area is located in Hungary, between the Danube and Tisza rivers, east of the southern slopes of the Cegléd-Gödöllő hills, at the confluence of the Tápió and Hajta rivers, between Tápiószele and Abony. The climate of the area is characterized by moderately warm and dry weather. In the southern and southeastern parts of Tápiószele, the dominant soil type is the highly fertile lowland chernozem with lime accumulation. In the northern and northeastern parts, brown sandy soil predominates. The soil conditions provide excellent conditions for agricultural production, particularly for arable farming and fruit growing. In the region, extensive orchards are used to grow various fruits. These include apricots, cherries, sour cherries, and plums. We conducted our study in a 5-hectare plantation, which had a total area of 16,500 m^2. We conducted our experiment with two types of fruit: sour cherry (Prunus cerasus) and plum (Prunus domestica).

The sample area was designated as follows. For each fruit, the size of the treated areas was 4,140 m^2 each. The treated areas were compared to control areas, each of which was the same size as the treated area. The treatment on the sample area was carried out in four repetitions for each fruit. The area of the repetitions was 284 m^2 for sour cherry and 280 m^2 for plum. The distribution of the areas is well illustrated in *Figures 1* and *2*, where L represents the aerated area and K represents the control area.

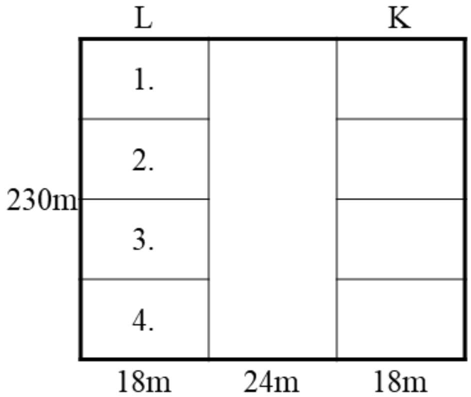

Fig. 1: Sour cherry experimental area

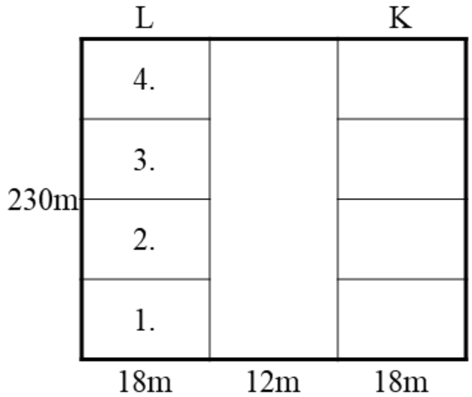

Fig. 2: Plum experimental area

The sour cherry variety examined in the experiment is ‘Érdi bőtermő’, which is a high-yielding, consistently productive, mid-early ripening variety (Gyúró, 1974). These characteristics have favored its spread in Hungary, where its occurrence reaches 50%, but the Maliga variety is also similarly popular (Soltész, 1997). The ‘Érdi bőtermő’ variety was bred by Pál Maliga and János Apostol through the crossbreeding of the ‘Pándy’ and ‘Nagy angol’ sour cherries. It received state recognition in 1970. In terms of its shoot system, the tree has a moderately vigorous growth, with a spreading branch system, dense, slightly flattened spherical crown. Its branches are prone to splitting. The leaves are elliptical or inverted egg-shaped. It bears fruit early, regularly, and as its name suggests, it is very prolific (https 9). The flowers of the ‘Érdi bőtermő’ bloom early, usually in early or mid-April (https 10). This variety is self-fertile, but for better yields, it may be beneficial to plant other early-blooming sour cherry varieties nearby, such as ‘Pándy meggy’ or ‘Érdi jubileum’ (https 11). Its fruit ripens early, in the second half of June, and is medium-sized (5-6 g), with a flattened spherical shape at the stem end. The skin is moderately thick, carmine red, shiny, smooth, dry to the touch, and attractive. The flesh is semi-firm, finely fibrous, juicy, with staining juice, pleasantly sweet-tart, and delicious. The stone is small. It is excellent for fresh consumption, culinary processing (canned, juice, jam), and freezing. It is less picky about soil requirements, but it thrives best in well-drained, humus-rich, nutrient-rich, medium-textured loam soil. It struggles in cold, poorly drained, heavy clay, and highly acidic soils. It has high light and heat requirements; its fruits are juicier and tastier in sunny locations compared to partial shade. Its water requirement is moderate. In dry, rainless springs, regular watering before flowering helps with fruit set, and later supports fruit development and the formation of fruit-bearing parts. It requires regular pruning. In its youth, this mainly involves shaping the crown, and later thinning and rejuvenation (https 9). Its virus resistance can be considered moderate. Although it generally resists various diseases well, it may be susceptible to some viral infections. It is moderately prone to monilial infection, especially in rainy weather. Its resistance to viral and fungal diseases is also moderate, so regular plant protection and spraying are important (https 11).

The chosen plum variety is 'Elena', which spread in our country in the 2000s (https 5). The 'Elena' plum originates from Stuttgart, Germany, where Dr. Walter Hartmann bred it at the University of Hohenheim by crossing the 'Fellenberg' and 'Stanley' varieties in 1980. It was commercially released in 1995 (Hartmann, 1998; https 12). It bears fruit regularly, but ripens late, in mid to late September (https 13). Due to its high sugar content, it is a favored ingredient in both the confectionery and canning industries (https 5). The tree initially has strong growth, later becoming moderately vigorous, with an upright, loose structure and a wide crown. The leaves are oval, shiny, and bluntly toothed. The fruits are medium-sized (approximately 35-40 mm long, 30 mm wide, 29 g), elongated, and characteristically plum-shaped. The skin is dark blue and frosted. The flesh is yellowish-green to golden yellow, firm, juicy, sweet, spicily flavorful, aromatic, and fragrant. The stone is freestone. They are excellent for fresh consumption and culinary processing (canning, jam, drying), and they store well (https 12). The blooming period of the 'Elena' plum falls in the moderately late season, which means that spring frosts rarely damage the flowers. This variety is self-fertile, so it does not require other plum varieties for pollination (https 13), however, some varieties that bloom at the same time can enhance its pollination. These include 'President', 'Stanley', 'Cacanska lepotica', 'Tophit', and 'Hanita' (https 14). Its soil requirements include good water and air management, rich in humus and nutrients, moist, deep-layered, medium-heavy soil. It does not have high demands on the soil, but it does not like saline soil. Its light and heat requirements are moderate, and it can tolerate slight shading. Its water needs are moderate, thriving well with approximately 600 mm of evenly distributed annual precipitation. Therefore, it needs to be irrigated during long, dry periods. In case of prolonged lack of rainfall, it drops its fruits. Pruning work should focus on shaping the crown until the tree is 4-5 years old. After it starts bearing fruit, thinning should be done to ensure the crown is airy and well-structured (https 12). In terms of virus resistance, the 'Elena' plum is particularly noteworthy as it is resistant to the Sharka virus, which affects many other plum varieties. This trait is especially important because the Sharka virus can cause significant crop loss, and infected trees often die (https 13).

We carried out soil aeration on April 4, 2024, at the beginning of the growing season, in both areas. During the operation, the machine injects air at a pressure of 12 bar into the soil using a 5 cm diameter, 82 cm long pressing spike (https 6), optionally on both sides of the fruit trees, as we applied in our experiment. The amount of air released from the spike during each pressing is 550 liters. This amount of air penetrates even deeper into the soil than the spike itself, reaching up to 150 cm (https 7). In Table 1, the area of the sour cherry and plum, as well as the total volume of air injected into the soil of the experimental areas, are shown in liters. In the tables, ML/SZL denotes the treated areas, and MK/SZK denotes the control areas. 'SZ' stands for plum treatment, and 'M' stands for sour cherry treatment.

Table 1

Size of treatments and the amount of air injected into them

Treatment	**ML**	**MK**	**SZL**	**SZK**
Treatment area size (m^2)	4140	4140	4140	4140
Amount of air injected (l)	156 200	-	154 000	-

The table clearly shows that the two crops received nearly the same amount of air.

In order to examine the compaction and soil moisture development of the control and soil-aerated areas, we conducted soil resistance measurements twice in the area. The first measurement took place on February 21, and the second one, after aeration, on May 8, using the Daróczi-Lelkes type Szarvas penetronic instrument. This instrument can determine soil resistance, which is an indicator expressing the relative degree of compaction (Gyuricza et al., 1998). In addition, it provides relatively quick and accurate data on the physical condition of the soil (https 9). Direct reading and storage of data are also possible, thanks to the device's data collection unit (https 8). In addition to compaction or looseness, soil resistance is also strongly influenced by soil moisture content (Rátonyi, 1999; Gyuricza, 2001b). Soil moisture content refers to the various concentrations and compositions of aqueous solutions present in the soil. Moisture content can vary significantly in both space and time (Stefanovits, 1992). However, it can be easily determined from the Arany's soil plasticity index. This index indicates how many cm^3 of water 100 g of air-dry soil can absorb before becoming saturated (https 4).

Before starting the experiment, we conducted soil sampling at the experimental site, with 4 repetitions. The main purpose of the examination was to determine the physical parameters of the soil in the studied area for soil aeration. However, the obtained test results also provided information about the chemical properties of the soil.

RESULTS AND DISCUSSION

The data and results of the measurements and examinations conducted during the experiment are presented in the form of tables and graphs.

Table 2

Soil test results

Analyzed parameter	Unit of measurement	Test results				Average
pH (KCl)		7.36	7.30	7.79	7.99	7.61
K_A		26	29	26	26	27
Total water-soluble salinity	% m/m					
$CaCO_3$	% m/m	1.2	3.5	2.8	3.9	2.9
Humus	% m/m	1.21	1.47	0.55	0.29	0.88
(Nitrite+Nitrate) Nitrogen	mg/kg	1.16	1.75	1.36	1.40	1.42
Phosphorus Pentoxide	mg/kg	255	132	152	89	152
Potassium Oxide	mg/kg	118	87.7	82.3	57.6	86.4
Magnesium	mg/kg	109	150	40	33.9	83.2
Sodium	mg/kg	< 5.00		< 5.00	5.35	5.11
Zinc	mg/kg	1.75	0.94	1.09	0.82	1.15
Copper	mg/kg	5.10	1.89	4.16	1.95	3.28
Manganese	mg/kg	166	50.1	67.2	36.6	80
Sulfur	mg/kg	< 2.50	< 2.50	< 2.50	< 2.50	< 2.50

The results of the soil sample analysis taken prior to the experiment setup are illustrated in Table 2. The table presents the properties of the soil samples taken from all 4 repetitions, as well as their averages. For the analysis of the results, we based our findings on the average of the 4 repetitions. This table also includes chemical parameters, but we are primarily interested in the physical parameters of the soil. Therefore, it is worth highlighting the Arany's binding number, which is 27 in our study area. This means that our soil type is sand in terms of water retention, although there are slightly clayey patches in the area, the predominant soil type is still sand.

Furthermore, it is worth mentioning based on the soil test results that the average humus content of the soil in our experiment is 0.88%, which is considered medium for sandy soil. However, certain average samples show higher values, which fall into the adequate (1.21%) and even good (1.47%) supply categories. This information is significant for our experiment because we are also measuring soil moisture, and higher humus content favors moisture retention.

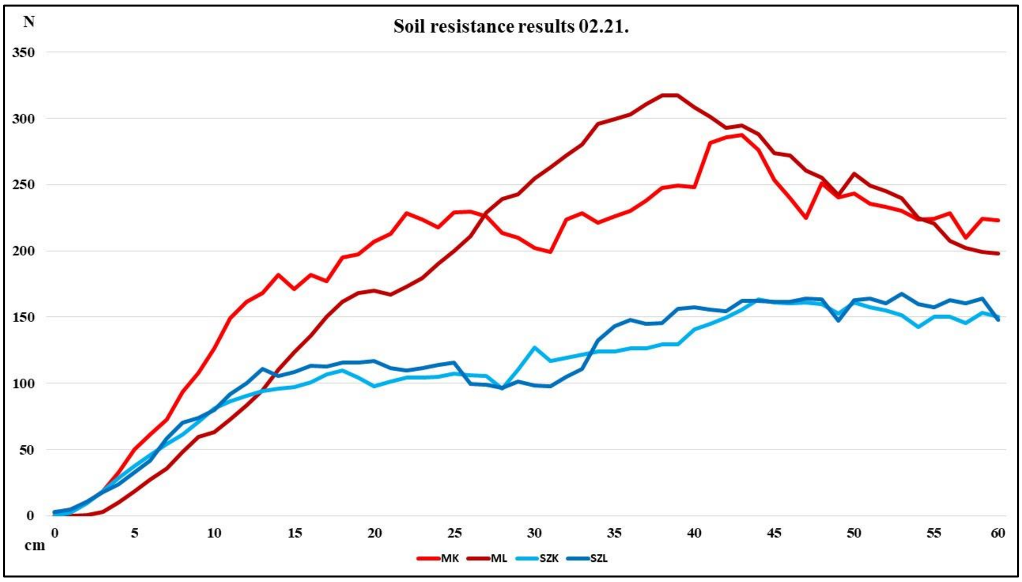

Fig. 3: Soil resistance values before soil aeration

After summarizing the data from the measurements conducted with the Daróczi-Lelkes type Szarvas penetronic instrument, we present the soil resistance and soil moisture results in the form of graphs. *Figure 3* illustrates the soil resistance results before soil aeration, while *Figure 4* shows the results after soil aeration. During the February measurements, it can be observed that much lower soil resistance values are seen in all four treatments compared to the measurements conducted in May. This is due to the higher soil moisture at the end of winter. It can also be concluded from the February measurements that there is no significant difference in soil compaction between the control and future treated areas for both fruits. Therefore, the experimental areas started with roughly similar soil conditions before the experiment began. Furthermore, it can also be observed from the February measurements that in the case of cherry soil, the soil resistance continuously increased up to a depth of 40 cm (320N), then gradually began to decrease in deeper layers. In contrast, for plum soil, the soil resistance increased up to a depth of 40 cm (170N) and remained the same in the deeper layers. Additionally, it can be seen that the soil of the cherry orchard shows a higher degree of soil compaction compared to that of the plum orchard. Considering all these factors, it can be concluded that the soil structure of the two orchards differs from each other. It is likely that the soil of the plum orchard contains more sand fractions.

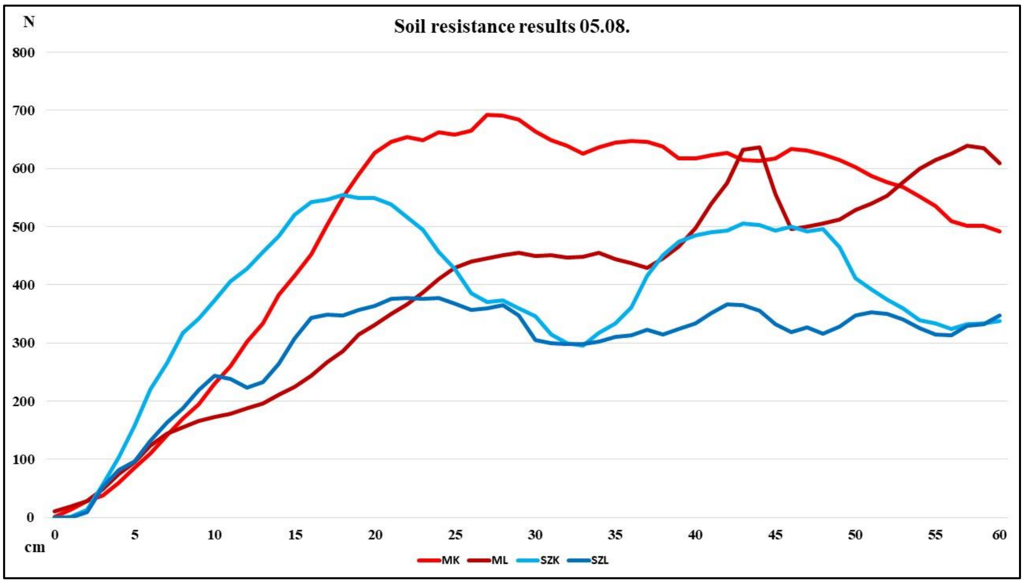

Fig. 4: Soil resistance values after soil aeration

From the data of the soil resistance measurements after soil aeration, it can be seen that the aerated treatments for sour cherry showed much lower soil resistance between depths of 10-45 cm, and for plum, the aerated treatments showed significantly lower soil resistance at depths of 10-20 cm and 40-50 cm compared to the control. This is due to the effect of soil aeration. Based on this, it can be stated that even a few weeks after soil aeration, the intervention already has a detectable effect on the looseness of the soil.

Figure 5 illustrates the soil moisture values before soil aeration, while *Figure 6* shows the values after soil aeration. From the February soil moisture values, it can be seen that the soil of the plum orchard has a higher moisture content. At a soil depth of 35-40 cm, values of 22% by volume can be observed in almost all examined soil depths. In contrast, the soil of the cherry orchard shows average values of only 15-18% by volume in one of the examined treatments, and even lower values, averaging 12-14% by volume, in the other examined area. However, unlike the plum orchard, not all soil depths show the same soil moisture in the cherry orchard. Starting from a soil depth of about 45 cm, the soil moisture gradually begins to increase in both examined areas within the cherry orchard. In one area, it reaches 21% by volume at a depth of 60 cm, while in the other area, it only reaches 19% by volume at the same depth. Based on this, it can be stated that within the plum orchard, both treatments started with approximately the same soil moisture, while there was a difference in soil moisture between the two treatments in the cherry orchard. The area where soil aeration was later performed showed lower soil moisture.

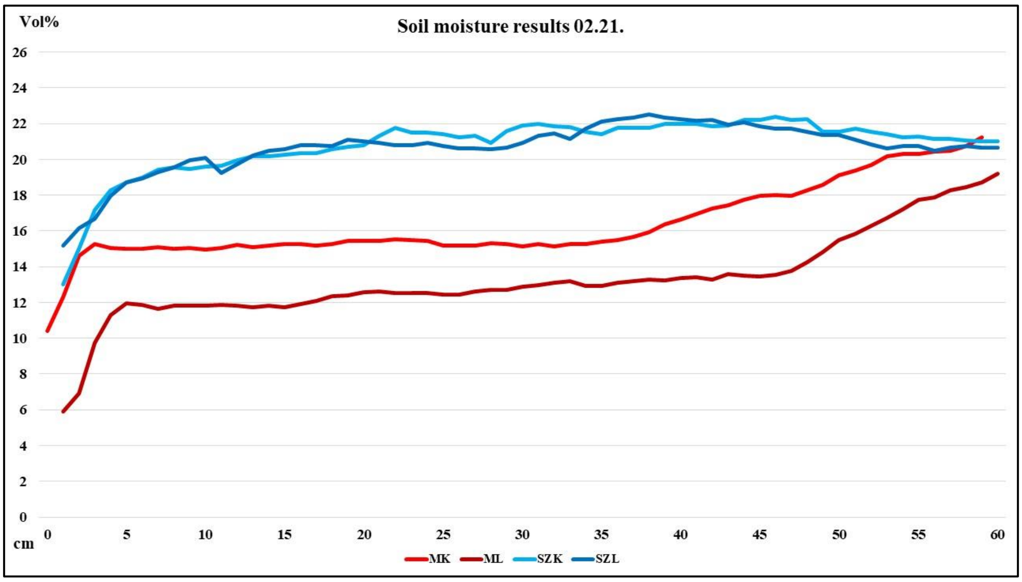

Fig. 5*:* Soil moisture values before soil aeration

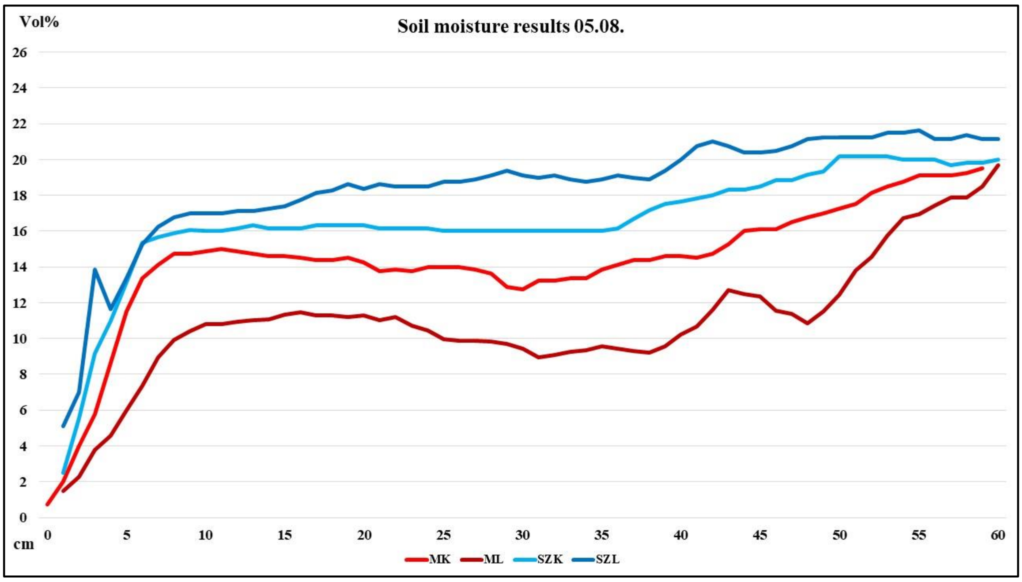

Fig. 6: Soil moisture values after soil aeration

After soil aeration, the soil moisture values varied between the two orchards. Overall, it can be stated that the soil moisture remained higher in the plum orchard, within which the aerated area showed higher soil moisture values at almost all examined soil depths. Here, the better water absorption capacity of the looser-structured soil can be clearly observed immediately after soil aeration. In the case of the cherry orchard, the soil moisture results were reversed. Unlike the plum orchard, the control area's soil showed higher soil moisture values, similar to the results of the February measurements. However, one positive effect can be observed: the upper layers (10-25 cm) of the aerated area's soil contain slightly more moisture (11% by volume) than the layers directly below. This can be attributed to the positive effect of soil aeration.

Comparing the soil resistance and soil moisture results, it can be concluded that the plum orchard, unlike the cherry orchard, showed lower soil resistance values but had higher soil moisture.

CONCLUSIONS

Overall, it can be stated that soil aeration shows remarkable results even in the first year, just a few weeks after the intervention, particularly in terms of soil resistance, but also in soil moisture. However, to accurately assess the positive effects of soil aeration, further detailed studies on soil structure over several years are necessary. Nevertheless, the results so far have already highlighted the importance of soil aeration.

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