South Western Journal of *Vol.15, No.2, 2024*
Horticulture, Biology and Environment *pp. 123-134*
P-ISSN: 2067- 9874, E-ISSN: 2068-7958 Art.no. e24108

INTENSIVE TECHNOLOGIES IN ORCHARDS: SOIL EFFECTS AND SUSTAINABLE MANAGEMENT STRATEGIES

Sina Niculina COSMULESCU*, Nicolae GHEORGHIU, and Ana Maria STOENESCU

Faculty of Horticulture, University of Craiova, 13 A.I. Cuza Street, 200585 Craiova, Romania
* Corresponding author: S.N. Cosmulescu, E-mail: sina.cosmulescu@edu.ucv.ro

ABSTRACT. *The intensive technologies used in orchards can lead to chemical and physical soil imbalances. It is essential to constantly monitor these characteristics to prevent soil degradation and ensure the sustainability of the orchard. This paper aims to analyze how technologies have influenced the physical and chemical characteristics of soil and provide recommendations for appropriate soil management. For soil analysis, the profile method was used, the observations made concerned the texture, hygroscopicity coefficient, soil reaction (pH), total carbonate content ($CaCO_3$), humus, total nitrogen, mobile phosphorus, and potassium, sum of exchangeable bases, ability to cation exchange (T) and degree of saturation in bases. The analysis carried out revealed differences in terms of physical and chemical characteristics on depth horizons and recommended specific management for each analyzed parameter. By adopting proper management, based on continuous monitoring and adjustment, soil quality can be maintained and sustainable productivity of the orchard can be ensured.*

KEYWORDS: *soil, texture, hygroscopicity coefficient, nitrogen, phosphorus, potassium index*

INTRODUCTION

Soil profile studies and soil management techniques are critical to ensuring the long-term health and productivity of an orchard ecosystem. These studies provide detailed information on the physical, chemical, and biological characteristics of the soil, allowing the implementation of management practices adapted to the specific needs of the orchard (Telak et al. 2021, Gheorghiu et al. 2023). Soil formation results from rock transformations due to climatic factors, organisms, and microorganisms. Soils in intensive fruit orchards can undergo degradation independent of climate or soil type (Paltineanu et al. 2016, 2020), and soil variability influences agricultural practices, nutrient, and pesticide management, as well as sustainable development (Umali et al. 2012). Maintaining and improving soil quality requires understanding the responses of soils to applied practices over time and the ability to measure or monitor quantitative changes (Goh et al. 2001). Production capacity and fruit quality are influenced by natural factors such as climatic and edaphic conditions, plant nutrition processes depending on fertility, water requirements, biological properties of the scion/rootstock system, and technological factors regarding soil work and orchard maintenance (Kopytko et al. 2017). Soil fertility refers to the ability of the soil to support plant growth and development by providing the necessary nutrients resulting from physical, chemical and biological activities (Srivastava et al. 2021). Intensive fruit orchards are characterized by high productivity and a short life span of the orchard, influenced by soil management and maintenance works (Polverigiani et al. 2018). As modern technologies are applied to soil management, its fertility undergoes substantial changes from the original natural state of uncultivated soil. At the same time, soil management influences plant growth and productivity (Sánchez et al. 2007). The analysis of physical and chemical characteristics is essential for managing soil resources, correct application of fertilizers, appropriate irrigation, and technological works applied to the soil (Singh et al. 2022). Soil characteristics are reflected in a soil profile, a sequence of constitutive layers/horizons, each with distinct characteristics due to pedogenetic factors (climate, geology, soil age, existing biodiversity, water sources, and anthropogenic activities). The work aimed to analyze the physical and chemical characteristics of soil from an apple orchard under the influence of intensive technologies and to recommend specific soil management within the orchard ecosystem.

MATERIALS AND METHODS

Location of the experience

The experience was located in an apple orchard, in Orodel (44°13'N 23°16'E), Dolj County, South-West area of Romania, in a super-intensive apple orchard (18-yearsold orchard), with a natural grassy cover system. The study area is part of the Caraula administrative territory, from the Oltenia Plain. The land surface is quasi-horizontal, with a water table depth of >10 m, showing well-drained soil on the surface and poorly drained in depth. The technological works applied to the soil before the establishment of the fruit orchard were land clearing, scarification, modeling, and plowing.

Soil analysis - profile method

To determine the characteristics of the soil in the orchard, a soil profile was made by digging a rectangular pit (100 x 165 cm). Visual observations tracked the morphological characteristics of the soil. To carry out the determinations in the laboratory, samples were taken from each horizon. The analysis methods used were those described by ICPA (2011). The hygroscopicity coefficient was determined by the Mitscherlich method; soil reaction (pH) was determined potentiometrically in an aqueous solution (1:2.5); the total carbonate content ($CaCO_3$) was determined by the Scheibler method; humus (H) was determined by wet oxidation, Walkley-Black method; total nitrogen (Nt) was determined by the Kjeldahl method; mobile phosphorus and potassium were determined using the Egner-Riehm-Domingo method; the amount of exchange bases (SB) was determined by the Kappen method (0.1n HCl); cation exchange capacity (T) represents the sum of exchangeable hydrogen and exchangeable bases; the degree of saturation in bases was determined according to the classes of saturation in bases (eubasic with values between 76-90%; saturated in bases >91%).

Statistical analysis

Statistical analysis was performed with IBM SPSS Statistics 26 software. One-way ANOVA and Duncan tests at $p < 0.05$ were used.

RESULTS AND DISCUSSION

Following the soil profile, a reddish preluvosol (EL rs) was highlighted, a component of the luvisol class (LUV) with the following horizons: Ao, AB, Bt1, Bt2 and Cca. The reddish preluvosol-type soil occupies an area of approximately 760.000 ha in Romania, respectively 5.24% of the total agricultural area (Călina & Călina 2019). The main characteristic of preluvosols according to the Romanian soil taxonomy system is the Argic B horizon (Bt) having colors with values and chroma over 3.5 (wet) starting from the upper part and a degree of saturation in bases over 53% (Florea & Munteanu 2012). The parent materials of this soil come from sedimentary rocks, being made up of loessoid deposits, clays, conglomerates, etc. Table 1 presents the main morphological characteristics of the soil profile.

Table 1. The main morphological characteristics of the soil profile

Horizon	Depth (cm)	Morphological characteristics
Ao	0-25	- dark grayish brown color, 7.5YR in wet condition, subangular polyhedral structure, weakly plastic, weakly compact, weakly cemented, does not effervesce, forms thin and medium roots with gradual transition to AB horizon.
AB	25-35	- dark grayish brown color, 7.5YR, ash, glomerular structure, medium plastic, medium adhesive, uncemented, with gradual transition to the Bt1 horizon.
Bt1	35-85	- dark brown color, 7.5YR, clay-loam texture, well structured, medium plastic, medium adhesive, does not effervesce, clear transition to Bt2 horizon.
Bt2	85-140	- dark brown color, loamy-clay texture, well structured, medium plastic, medium adhesive, does not effervesce, gradual transition to the horizon Cca.
Cca	140-165	- olive gray 5Y5/2 loosely friable structured, strong effervescence, large accumulations of $CaCO_3$.

Following the statistical processing of the obtained data (one-way ANOVA), there were significant differences found between soil horizons ($p<0.05$), highlighted by the results of the Duncan tests (Tables 2, 3, and 4).

Soil texture influences many physical soil properties, including water-holding capacity, drainage, and aeration. According to the data obtained (Table 2), the percentage of coarse sand, fine sand, dust, clay was different according to the horizon: coarse sand with variations between 4.9 (Bt2) to 8.6% (Cca); fine sand with variations between 28.7 (Bt1) and 45.4% (Cca); dust with variations between 14.8 (Cca) and 31.6 (Ao); clay with variations between 31.2 (Cca) and 46.7% (Bt1). The results obtained are consistent with those obtained by Călina & Călina (2019) regarding the reddish preluvosol in the Coșoveni area, Dolj County. Managing soil characteristics in orchards is crucial to ensuring long-term tree health and productivity. Comparatively analyzing specific horizons, it is found that each one with distinct characteristics of soil composition requires specific management.

The Ao horizon (0-15cm) has approximately equal proportions of fine sand (30.2%), dust (31.6%), and clay (31.9%), indicating a loamy texture, a soil-balanced in water retention and drainage. The balanced proportion of fine sand, dust, and clay allows good retention of water and nutrients, reducing the risk of their washing away and ensuring continuous availability for plants (Zhang et al. 2021). At the same time, the loamy texture facilitates adequate aeration, essential for root health and beneficial microbial activity. The AB horizon (15-35 cm) has approximately equal proportions of fine sand (35.7%) and clay (34.6%), which indicates a clay-loam texture and represents a transition between the topsoil and the lower layers, having an important role in supporting the soil structure. The horizon Bt1 (35-85cm) and Bt2 (85-140cm) is characterized by a high percentage of clay (45.9-46.7%), which indicates high water-holding capacity, which can lead to compaction and poor drainage. The Cca horizon (140-160cm) shows a high percentage of fine sand (45.4%), which indicates a lower water and nutrient retention capacity compared to clay. In these conditions, based on the analysis of the soil texture, appropriate management is recommended in the fruit orchard, which takes into account soil fertility, water retention, and aeration characteristics. In fruit growing, an important problem is the annual supply process with chemical fertilizers, which overestimated can lead to water and soil pollution (Sumedrea et al. 2013).

Table 2. The granulometric characteristics of the soil and the hygroscopicity coefficient (*Different letters indicate statistically significant differences ($p<0.05$))

Horizon		Ao	AB	Bt1	Bt2	Cca
Depth of the horizon (cm)		0-25	25-35	35-85	85-140	140-160
Coarse sand	(2.0 - 0.2 mm) %	6.3^{c*}	6.9^{b}	5.1^{d}	4.9^{e}	$8,6^{a}$
Fine sand	(0.2 - 0.02 mm) %	30.2^{d}	35.7^{b}	28.7^{e}	30.5^{c}	$45,4^{a}$
Dust	(0.02 - 0.002 mm) %	31.6^{a}	22.8^{b}	19.5^{c}	18.7^{d}	$14,8^{e}$
Clay	(<0.002 mm) %	31.9^{d}	34.6^{c}	46.7^{a}	45.9^{b}	$31,2^{e}$
Physical clay	(<0.01 mm) %	-	-	-	-	-
Coefficient of hygroscopicity (CH %)		5.4^{e}	7.1^{d}	8.8^{c}	10.8^{b}	11.1^{a}

In terms of nutrient management, the balanced texture of the Ao horizon indicates fertile soil with good nutrient retention capacity, ideal for plant growth. The AB horizon, with a significant clay content, suggests good nutrient retention but requires proper management to avoid drainage problems. The Ao horizon provides a balance between water retention and drainage, which is beneficial for trees in the first years after planting and intense biological activity. The AB horizon, due to its high clay content, retains water well but requires monitoring to prevent excess moisture and compaction. Bt1 and Bt2 horizons require careful water management to prevent excess and compaction. Aeration is adequate in the Ao horizon due to the loamy texture, favoring root health and microbial activity. In the AB horizon, the proportion of clay can reduce aeration, so the use of decompaction techniques and the addition of organic matter is important. Periodic use of decompaction techniques is recommended in Bt1 and Bt2 horizons to maintain soil porosity and ensure good aeration for tree roots. By understanding these horizons and their properties in detail, important soil management decisions can be made, which will help maximize crop productivity and sustainability (Sheng et al. 2020).

The coefficient of hygroscopicity (CH %) had values between 5.4% (Ao horizon) and 11.1% (Cca horizon) and depends on the size and nature of the soil particles. The smaller the soil particles are, the larger the surface area per unit volume. That is why soils with fine particles (clay, clay-loam) have higher hygroscopicity, and sandy soils have low hygroscopicity. In the case of fruit orchards, these values can provide essential information for managing water and soil fertility. According to the data obtained through soil analysis, in the experimental orchard, the values of the hygroscopicity coefficient varied according to the horizons. The Ao horizon (0-15cm) with a low CH value (5.4%) indicates that this layer retains relatively little moisture from the soil air. AB horizon (25-35cm) – moderate CH value (7.1%) indicates that this horizon retains a decent amount of moisture, suggesting a good balance between water retention and drainage. Bt1 horizon (35-85cm) – high CH value (8.8%) indicates higher moisture holding capacity, often associated with higher clay content (46.7%). The Bt2 horizon (85-140cm) with a high CH value (10.8%) indicates that the soil has excellent moisture-holding capacity, but has a higher risk of compaction and poor drainage (45.9% clay). The Cca horizon (140-160cm) with a high CH value (11.1%) indicates that this layer has a high capacity to retain moisture, which requires careful monitoring to avoid large moisture fluctuations.

Table 3. Characteristics of pH, carbonate and humus content

Horizon	Ao	AB	Bt1	Bt2	Cca
Depth of horizon (cm)	0-25	25-35	35-85	85-140	140-160
pH in H_2O	6,12^{e*}	6,32^{d}	6,66^{c}	6,75^{b}	7,94^{a}
Carbonates $CaCO_3$, (%)	-	-	-	-	15,7^{a}
Humus (%)	2,43^{a}	2,21^{b}	1,73^{c}	1,50^{d}	0,45^{e}

In conclusion, the increase in the hygroscopicity coefficient from the surface to the depth of 160 cm (Cca horizon) indicates a variation in the soil's ability to retain moisture, influenced by the increase in clay content. By adopting soil management strategies, including irrigation, loosening, and adding organic matter, an optimal environment for the growth and development of fruit trees can be ensured (Abobatta 2021).

The soil reaction is a key edaphic factor that regulates bacterial community distribution and functions along vertical soil profiles (Muneer et al. 2022). The analyzed soil pH varied with horizon and depth as follows: 6.12 (horizon Ao), 6.32 (horizon AB), 6.66 (horizon Bt1), 6.75 (horizon Bt2), and 7.94 (horizon Cca), from weakly acidic to weakly alkaline. According to Radu et al. (2019), soil pH directly affects nutrient mobility and accessibility. These variations reflect changes in soil texture and chemical composition as depth increases (Table 3). From the point of view of management in fruit orchards, the pH values on depth horizons involve the application of specific measures: for the Ao horizon (pH = 6.12) it is recommended to use fertilizers that do not lower the pH and the addition of compost for buffering the pH, or applying limestone to raise the pH slightly if needed; for the AB horizon (pH = 6.32) it is recommended to add compost and use fertilizers that maintain the pH; for horizon Bt1 (pH = 6.66) and Bt2 (6.75) it is recommended to use balanced fertilizers that keep the pH close to neutral. The slightly alkaline Cca horizon (pH = 7.94) favors the availability of certain nutrients but can reduce the availability of others such as iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) and this can lead to nutritional deficiencies manifested by symptoms such as leaf chlorosis. In conclusion, by carefully monitoring pH and adapting soil management strategies, an optimal environment for fruit tree growth can be ensured. Adapting fertilization, irrigation, and soil improvement to the specific pH of each horizon will contribute to the long-term health and productivity of fruit orchards.

The presence of calcium carbonates ($CaCO_3$, %) in a significant percentage (15.7%) in the Cca horizon (140-160 cm) indicates a calcareous soil and this can influence various physical and chemical properties of the soil. A high $CaCO_3$ content is often associated with an alkaline pH, which is also visible in the determinations made (pH=7.94), confirming this aspect (Table 3). Calcareous soil is one of the most limiting edaphic factors for the production of good-quality fruits (Mirabdulbaghi 2022). The presence of $CaCO_3$ at depths of 140-160 cm can influence root development. In some cases, roots can avoid very calcareous layers, which can limit the depth to which they extend, with significant implications for fruit growing. By implementing appropriate amendment, fertilization, and irrigation management strategies, one can maximize the benefits and minimize the challenges associated with calcareous soils.

Regarding the **amount of humus** (Table 3), the results obtained varied between 0.45 (Cca horizon) and 2.43% (Ao horizon) and this difference reflects the level of biological activity and the decomposition process of organic matter, being essential for soil fertility (Nardi et al. 2021). The humus-rich Ao horizon is crucial for plant support, while the lower Cca horizon indicates a less biologically active area. A higher humus content (2.43% in the Ao horizon) improves soil fertility, providing essential nutrients to fruit trees, and at the same time, humus contributes to a better soil structure, improving drainage and water retention, essential aspects for root health. The presence of humus also stimulates the activity of microorganisms, which help decompose organic matter and release nutrients, the soils being more resistant to humidity fluctuations and climatic stress, helping the trees to cope with adverse conditions. Depending on the variability of humus between horizons, it is necessary to implement some soil management strategies to maintain or improve the humus content in fruit orchards, one of the methods being the application of grass strips.

The soil nitrogen index reflects the amount of nitrogen available in the soil, which is essential for plant development and is an important indicator of soil fertility. The nitrogen index is influenced by the type of soil (clay soils retain nitrogen better than sandy ones), by biological activity (microorganisms in the soil contribute to the decomposition of organic matter and the mineralization of nitrogen), by applied management practices (fertilization and degradation of plant residues influence the level of nitrogen in the soil) (Folina et al. 2021). Low nitrogen index values (0.45-1.5%) indicate nitrogen-poor soils, which can limit plant growth and require adequate fertilization, and this is visible in the 35-160 cm depth layer. Moderate nitrogen index values (1.5-2.5%) indicate soils with a medium level of nitrogen, up to a depth of 35 cm, suitable for vegetation development, but must be monitored to prevent excess nitrogen (Table 4). As a result, periodic soil analysis is needed to adjust fertilization management and the use of leguminous plants in intercropping schemes to improve soil nitrogen content.

Total nitrogen decreased significantly from the Ao horizon (0.126%) to the Cca horizon (0.023%), with important implications for soil fertility and fruit production. This suggests a need for interventions to improve soil nutrient content. Lower values in deep horizons indicate low biological activity, affecting the decomposition of organic matter. Such a large reduction in total nitrogen (5.47 times between the Ao and Cca horizons) can lead to a long-term decline in fertility, affecting tree health.

Table 4. Chemical characteristics of the soil in the experimental orchard at depth horizons (*Different letters indicate statistically significant differences (p<0.05))

Horizon	Ao	AB	Bt1	Bt2	Cca
Depth of the horizon (cm)	0-25	25-35	35-85	85-140	140-160
Nitrogen index (IN)	2.07^{b*}	2.21^{a}	1.58^{c}	1.50^{d}	0.45^{e}
N total (%)	0.126^{a}	0.115^{b}	0.090^{c}	0.078^{d}	0.023^{e}
P mobile (ppm)	45.3^{a}	34.1^{b}	26.7^{c}	18.5^{d}	6.3^{e}
K mobile (ppm)	163^{a}	132^{b}	112^{c}	76^{d}	21^{e}
Exchangeable bases (SB, me 100 g soil)	13.45^{d}	14.20^{c}	21.47^{b}	23.72^{a}	-
Exchangeable hydrogen (SH, me 100 g soil)	2.28^{a}	2.03^{b}	1.32^{c}	1.12^{d}	-
Total cation exchange capacity (T, me 100 g soil)	15.73^{d}	16.23^{c}	22.8^{b}	24.8^{a}	-
Degree of saturation in bases ($V_{pH\ 8.3}$, %)	85.5^{d}	87.5^{c}	94.2^{b}	95.6^{a}	-

The content of mobile phosphorus varied significantly between 6.3 ppm (corresponding to the Cca horizon) and 45.3 ppm (the Ao horizon). High levels of phosphorus in the Ao horizon (45.3 ppm) favor plant development and fruit growth, while low levels in the Cca horizon (6.3 ppm) can limit nutrient uptake and tree health. The large difference (7.2-fold) suggests nutrient accumulation in the upper layer but degradation in deeper layers, affecting long-term fertility. It is recommended to use phosphate fertilizers regularly to improve the phosphorus content of the soil and to carry out periodic analyses to follow the variations in the phosphorus content and adapt the fertilization strategies.

The mobile potassium content varied from 21 ppm (Cca horizon) to 163 ppm (Ao horizon). The Ao horizon (163 ppm) has a high potassium content, essential for the healthy development of trees and fruits, while the Cca horizon with a low content (21 ppm) can negatively affect plant growth and development. Potassium plays a crucial role in photosynthesis, water regulation, and stress resistance, and large differences between horizons can affect plant health (Kuzin & Solovchenko 2021), which requires constant monitoring of potassium content to adapt fertilization strategies.

Exchangeable bases (SB) represent the amount of positive cations (nutrients) that can be adsorbed by soil particles and this indicator is important for evaluating soil fertility. The obtained values above 13.45 me/100 g soil indicate moderate soils (SB between 5-15 me/100 g), which require careful management for the Ao and AB horizons, and rich soils (SB>15 me/100 g) favorable for fruit growing.

Exchangeable hydrogen (SH) represents the amount of hydrogen available in the soil and it influences soil acidity and nutrient availability. SH>2 me/100 g values indicate acidic soils, which is correlated with soil reaction, with the Ao and AB horizons having a slightly acidic pH. Hydrogen can influence the soil's ability to retain and exchange other cations, thereby affecting fertility.

Total cation exchange capacity (T) represents the sum of all exchangeable cations in the soil. A higher cation exchange capacity indicates a soil capable of retaining and supplying essential nutrients to plants, and soils with a high T are more resistant to nutrient fluctuations and climatic conditions. The values obtained varied between 15.73 (Ao horizon) and 24.8 me/100 g soil (Bt2 horizon), indicating moderate soils (T between 10-20 me/100) and rich soils (T>20 me/100 g), ideal for fruit growing. Periodic analyses are recommended to assess total cation exchange capacity and adapt fertilization strategies.

The degree of saturation in bases ($V_{pH\ 8.3}$) represents the proportion of basic cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) in the total cation exchange capacity, expressed in percentage (%), and is an indicator of soil health and its fertility. A high degree of saturation in bases indicates a healthy soil, capable of supporting optimal plant development. The values obtained varied between 85.5 (Ao horizon) and 95.6% (Bt2 horizon), indicating high saturation (V_{pH}>50%), favorable for most crops. In this case, periodic analyses are recommended to assess the degree of saturation and adapt fertilization strategies.

CONCLUSIONS

Considering the changes in the physical and chemical nature of the soils in fruit orchards, under the influence of intensive technologies, it is recommended to carry out periodic soil analyses to evaluate the effects of management practices and to adjust the strategies according to the needs of the soil. Management practices should aim to improve soil structure, manage nutrients, conserve moisture, and prevent soil erosion. By adopting these measures, it is possible to contribute to the conservation of the soil, the increase of biodiversity, and the creation of a sustainable orchard ecosystem, capable of offering high-quality production in the long term.

Acknowledgments
The paper is the result of the ADER 6.1.9 project: The influence of eco-schemes application on permanent crops in fruit plantations in the context of ensuring biodiversity and environmental impact.

REFERENCES

Abobatta, W.F. (2021): Fruit orchards under climate change conditions: adaptation strategies and management. Journal of Applied Biotechnology and Bioengineering 8: 99-102.

Călina, A., Călina, J. (2019): Research regarding the agriproductive properties of the typical reddish preluvosol between Jiu and Olt rivers and its evolution from 1997-2017 in farms and agritouristic households. Romanian Agricultural Research 36: 251-261.

Florea, N., Munteanu, I. (coord.). (2012): Sistemul român de taxonomie a solurilor (SRTS). Ed. Sitech, București.

Folina, A., Tataridas, A., Mavroeidis, A., Kousta, A., Katsenios, N., Efthimiadou, A., Kakabouki, I. (2021): Evaluation of various nitrogen indices in N-fertilizers with inhibitors in field crops: A review. Agronomy 11(3): 418.

Gheorghiu, N., Stoenescu, A.M., Cosmulescu S.N. (2023): Evaluation of some sweet cherry cultivars grafted on 'Gisela 6' rootstock. Scientific Papers. Series B. Horticulture 67(1): 95-99.

Goh, K.M., Pearson, D.R., Daly, M.J. (2001): Effects of apple orchard production systems on some important soil physical, chemical and biological quality parameters. Biological Agriculture & Horticulture 18(3): 269-292.

Kopytko, P., Karpenko, V., Yakovenko, R., Mostoviak, I. (2017): Soil fertility and productivity of apple orchard under a long-term use of different fertilizer systems. Agronomy Research 15(2): 444-455.

Kuzin, A., Solovchenko, A. (2021): Essential role of potassium in apple and its implications for management of orchard fertilization. Plants 10(12): 2624.

Mirabdulbaghi, M. (2022): Fruit mineral content and yield of some pear cultivars grown under limited environmental conditions. Erwerbs-Obstbau 64(4): 603-609.

Muneer, M.A., Hou, W., Li, J., Huang, X., ur Rehman Kayani, M., Cai, Y., Zheng, C. (2022): Soil pH: a key edaphic factor regulating distribution and functions of bacterial community along vertical soil profiles in red soil of pomelo orchard. BMC Microbiology 22(1): 38.

Nardi, S., Schiavon, M., Francioso, O. (2021): Chemical structure and biological activity of humic substances define their role as plant growth promoters. Molecules 26(8): 2256.

Paltineanu, C., Chitu, E., Sumedrea, D., Florea, A. (2020): Correlation between maximum trunk daily shrinkage, soil matric potential and weather variables for mature plum trees in medium-textured soils and temperate climate. Erwerbs-Obstbau 62(2): 201-211.

Paltineanu, C., Tanasescu, N., Chitu, E. (2016): Pattern of soil physical properties in intensive plum and apple orchards on medium and coarse-textured soils. Soil and Tillage Research 163: 80-88.

Polverigiani, S., Franzina, M., Neri, D. (2018): Effect of soil condition on apple root development and plant resilience in intensive orchards. Applied Soil Ecology 123: 787-792.

Radu, V., Popa, I., Dodocioiu, A.M., Buzatu, G.D. (2019): The quality status of the reddish preluvosol from ARDS Simnic. Annals of the University of Craiova, Biology, Horticulture, Food products processing technology, Environmental engineering 24(60): 213-217.

Sánchez, E.E., Giayetto, A., Cichón, L., Fernández, D., Aruani, M.C., Curetti, M. (2007): Cover crops influence soil properties and tree performance in an organic apple (*Malus domestica* Borkh) orchard in northern Patagonia. Plant and Soil 292: 193-203.

Sheng, Y., Wang, H., Wang, M., Li, H., Xiang, L., Pan, F., Chen, X., Shen, X., Yin, C., Mao, Z. (2020): Effects of soil texture on the growth of young apple trees and soil microbial community structure under replanted conditions. Horticultural Plant Journal 6(3): 123-131.

Singh, P., Srivastava, R., Meena, R.K., Patle, N., Meena, K., Meena, R, Singh, N. (2022): Soil profile studies under different orchard management system in Chhindwara District of Madhya Pradesh, India. International Journal of Plant & Soil Science 34(23): 711-717.

Srivastava, A.K., Wu, Q.S., Mousavi, S.M, Hota, D. (2021): Integrated soil fertility management in fruit crops: An overview. International Journal of Fruit Science 21(1): 413-439.

Sumedrea, D., Iancu, M., Chiţu, E., Sumedrea, M., Marin, C., Tănăsescu, N., Butac, M. (2013): Influence of black charcoal application on fruit yield and chemical properties of the soil in high density apple orchards. Acta Horticulturae 981: 355-360.

Telak, L.J., Dugan, I., Bogunovic, I. (2021): Soil management and slope impacts on soil properties, hydrological response, and erosion in hazelnut orchard. Soil Systems 5(1): 5.

Umali, B.P., Oliver, D.P., Forrester, S., Chittleborough, D.J., Hutson, J.L., Kookana, R.S., Ostendorf, B. (2012): The effect of terrain and management on the spatial variability of soil properties in an apple orchard. Catena 93: 38-48.

Zhang, J., Amonette, J.E., Flury, M. (2021): Effect of biochar and biochar particle size on plant-available water of sand, silt loam, and clay soil. Soil and Tillage Research 212: 104992.