ROMANIAN AGRICULTURAL RESEARCH, NO. 40, 2023
Print ISSN 1222-4227; Online ISSN 2067-5720

VARIOUS SOIL QUALITY PARAMETERS AND HUMUS CONTENT EVOLUTION IN CONVENTIONAL AND MINIMUM TILLAGE SYSTEMS

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ABSTRACT

An experiment was laid out on a Haplic Phaeozem (PH ha) (WRB-SR 2014) characterized by a dark colored mollic A horizon (Am), a cambic B horizon (Bv), and an accumulation calcareous illuviation horizon (Cca) of secondary calcium carbonates which occurs deeper than 125 cm (SRTS, 2012). Clay content in the first 40 cm varies between 39.4 and 42.6%, total nitrogen is 0.186%, available phosphorus soluble in the ammonium acetate lactate solution (P_{AL}) 76 mg/kg, available potassium soluble in the same solution (K_{AL}) 250 mg/kg, and soil reaction (pH) 6.3. The land is slightly uneven, groundwater below 5 m depth. The humus content was average in the beginning of the experimentations after which increases were noticed especially in the upper layer (5-10 cm). Soil humus content evolution following different agricultural technologies use was similar at all three studied depths, with increases in the case of minimum tillage system, but without statistically significant differences as compared to the classic one. Therefore, the various agricultural technological systems must assert the conservation and increase of soil organic matter, respectively, the soil humus supply, through their technological chain links.

Keywords: conservative agriculture, no-tillage, agricultural technologies, organic matter.

INTRODUCTION

Soil quality is influenced by the used farming system, mechanical works, irrigation regime and agricultural inputs, from fertilizers to plant protection products (Petcu and Ciontu, 2014; Petcu et al., 2014; Mărin et al., 2021; Sîrbu et al., 2022).

Soil tillage of conservative agriculture define at present extremely variated processes from sowing directly into unworked soil (no-tillage, direct drill) to deep loosening without turning the furrow (Burtan et al., 2016; Cizmaş et al., 2022). Variants lie between these two outrances such as: reduced tillage (conventional rationalized), minimum tillage without covering (with less than 3% covering), minimum tillage with vegetal mulch (more than 30% covering, mulch tillage), sowing on ridges (ridge tillage), partial tillage or in stripes (strip till, zone till), tillage with protective layer (cover crops, catch crops), etc. (Duda et al., 2014; Abagandura et al., 2017; Petcu et al., 2022). The differences between cropping technologies regarding soil tillage highlight the specific character which defines a certain procedure applied at a certain time, in some area, in concordance with the local particularities (Moroizumi and Horino, 2002; Çetin, 2021). Research carried out up to date showed the advantages of applying soil minimum tillage systems in the long run: diminishing soil erosion, better water seepage and holding in soil, soil organic matter increase, low costs, working time abatement, increased yields (Limon-Ortega and Sayre, 2003; Cheţan et al., 2022).

Received 30 November 2022; accepted 18 May 2023. First Online: May, 2023. DII 2067-5720 RAR 2023-124

Food and Agriculture Organization of the United Nations (FAO, 2023) defines conservative agriculture as ”agricultural production sustainable system for water and agricultural soil protection which integrates agronomic, environment, and economic aspects”. Wide research demonstrated that conservative agriculture improves physical, chemical, and biological soil properties which are crucial for soil health sustenance and agroecosystem endurance increase to global change (Stavi et al., 2016; Cociu and Alionte, 2017; Claassen et al., 2018).

Nevertheless, despite researches carried out for implementing the three conservative agriculture principles: minimum soil mechanical disturbance through soil preservation works (respectively without soil tillage, soil minimum tillage), soil permanent organic cover with crop residues and/or covering crops, and crops diversification through crop rotation and associations that imply at least three different crops (including a pulse crop), there are still many technical and social and economic aspects that limit their taking-up worldwide (Blanco-Canqui and Ruis, 2018; Peixoto et al., 2019; Francaviglia, 2023). The influence of the tillage system upon soil properties represents important factors for soil fertility conservation and agricultural system sustainability assessment (Almagro et al., 2017; Biddoccu et al., 2017; Martínez-Mena et al., 2021).

Soil humus content registers a growing tendency by applying soil minimum tillage system due to bigger vegetal leftovers quantities (minimum 30%) remained at the soil surface and in the upper layers of 10-20 cm in different decomposition stages, on one hand, and to the mineralization/ humification ratio balancing, on the other, reached through a specific physical, thermic, and biological condition. Humus determination after four years registers a growing tendency through minimum systems application, respectively, an up to approximately 0.41% growth. The registered values were 3.11% in the ploughed variant and 3.12-3.52% in the minimum tillage system (Guș and Rusu, 2011).

Researches carried out by Rusu (Rusu et al., 2002) showed that after three years of experimentations with different tillage systems variants, the humus quantity on the 0-20 cm depth varied between 2.28 and 3.39%, with an obvious growing tendency in the unconventional system variants.

In many studies the fact was shown that applying unconventional soil tillage systems and especially no-tillage system led to a higher level of organic carbon assimilation as compared to the conventional tillage system (Jităreanu et al., 2006; Ulrich et al., 2006; Gonzalez-Sanchez et al., 2019). Nevertheless, soil organic matter accumulation degrees variations can be found in studies depending on climatic conditions, soil characteristics, initial organic carbon levels, cropping type, growing systems, technological management, and experiments duration. The results of different analyses and modelling studies indicate organic carbon accumulation degree in soil ranging from 0.27 to 1.10 $t \cdot ha^{-1} \cdot year^{-1}$ when applying conservative agriculture (Aguilera et al., 2013; Sheehy et al., 2015; Pardo et al., 2017; Francaviglia et al., 2019). Vegetal remains represent important organic carbon sources and their positive effect in improving this element's soil content was noticed by several researchers (Lal, 1997; Nyakatawa et al., 2001; Yadav et al., 2017). Organic matter in a winter wheat crop represented by only plant roots was studied in an investigation carried out at USAMV Iași, in the Ezăreni Farm, in a crop rotation with 3 crops and 5 soil tillage variants, represented by disk harrow, paraplow, chisel, ploughing at 20 and at 30 cm. Contents were found ranging from 1.6 tons/ha in the paraplow variant to 2.5 tons/ha in the variant worked by chisel (Țopa and Cuconoiu, 2017).

In an experiment with soil working systems on a Haplic Chernozem with clayey loamy structure at the Ezăreni - USAMV Iași Didactic Station humus content growths were asserted in the 0-40 cm layer from 2.84-2.95% in the beginning of a three years experiment, especially in the upper layer. The 0-20 cm layer analysis shows higher values of the indicator, especially in the case of minimum tillage systems, with variations between

3.34% in the chiseled variant and 3.52% in the variant worked with the disc harrow. The conventional tillage variants present lower values: ploughed at 20 cm - 3.19%, and ploughed at 30 cm - 3.41%. On the 20-40 cm depth a more marked decrease is noticed only in the variants worked with the disk harrow and ploughed at 200 cm, but the modifications are rather small (Țopa et al., 2013).

MATERIAL AND METHODS

The studied area is located in the Romanian Plain, Teleorman Plain unit, Găvanu-Burdea Plain subunit. Genetically the Găvanu-Burdea Plain is a piedmont plain with absolute elevations between 80 and 200 m. The whole area is coated with a continuous cover of loess deposits 8-20 m thick under which clayey-marly villafranchian deposits, sands, and gravel are encountered. The climate is characterized by a high radiation potential which makes that the average yearly temperature oscillates around 10.5°C. Average yearly rainfall adds up to 503.1 mm and come under code 0525 average yearly rainfall according to MESP, ICPA 1987. The soil is Haplic Phaeozem (WRB-SR 2014), formed on carbonate loess loamy-clayey deposits with villafranchian clayey-marly deposits sublayer, tillable settled. The natural vegetation of the degraded secondary meadows is represented by: *Festuca valesiaca, Poa angustifolia, Polygonum convolvulus, Euphorbia virgata, Botriochloa ischaemum, Poa bulbosa, Cynodon dactylon*.

The results presented in this paper were obtained in a five-year experiment at SCDA Teleorman, on a Haplic Phaeozem (PH ha) (WRB-SR 2014) characterized by a dark colored mollic A horizon (Am), a cambic B horizon (Bv), and an accumulation calcareous illuviation horizon (Cca) of secondary calcium carbonates which occurs deeper than 125 cm (SRTS, 2012). The clay content on the 0-40 cm depth varies between 39.4 and 42.6%, total nitrogen (Nt) is 0,186%, available phosphorus and potassium soluble in the ammonium acetate lactate solution (P_{AL} and K_{AL}) are 76 mg/kg and 250 mg/kg, respectively, and soil reaction (pH) is 6.3. The land is very slightly uneven and the groundwater depth is below 5 m.

Two soil working systems were tested on a 4 ha area, conventional tillage system and minimum system (direct sowing). Land preparation in no-till system was done without preparing the seedbed, through a single sowing machine (model Fabimag FG-01 63A175) pass, working in combiner with John Deere 8360R tractor, directly in the stubble. In classical system a summer ploughing was done at 18-20 cm depth, agrotechnical works were completed by discing with a CASE 7240 tractor, combiner works, and sowing. Complex 20-20:0 fertilizers were applied in 200 kg/ha dose in the autumn and nitro calcar 200 kg/ha in the spring. Agro physical profiles were dug in the soil and samples were taken by 5-10; 25-30; and 45-50 cm depths. The analyses and determinations were performed according to current methodology and standards (SRTS, 2003; MESP, vol. I-III, 1987) (Florea et al., 1987, 2012).

RESULTS AND DISCUSSION

Soil quality

The main problems arisen by the soils of the studied area are determined by the high clay content, with uneven distribution on the soil profile, by the high toughness state, and surface water excess, sometimes intensified by the groundwater low depth. As a consequence, the air and water condition are deficient, the demand for soil loosening is high, the traffic and soil working conditions are frequently worsened.

These soils suitability for conservative tillage systems is low due to the specific inherent characteristics.

Still, the conventional technology applied year after year on such soils, subject to degradation processes by compaction and water excess, only led, over time, to the intensification and widening of these processes which at the present affect considerable areas.

Physical and hydro-physical characteristics. The colloidal clay (<0.002 mm) content varies on the soil profile between 42.7 to 44.3%, down to 105 cm depth in the Ck horizon and decreases further to 40.6-40.8%. Silt (0.02-0.002 mm) content remains relatively even on the profile with 27.3-30.9% values, the fine silt (0.2-0.02 mm) has 27.2-29.2% values, the coarse silt (2-0.2 mm) is low, with 0.2-0.8% values. From the particle-size distribution point of view the soil is framed in the medium-fine loamy-clayey structure category on the whole profile. The bulk density (BD, g/cm^3) is medium with 1.41-1.42 g/cm^3 values in the upper Ap, Apt, and Am horizons, down to 47 cm depth, and high, with 1.45-1.50 g/cm^3 values in the A/B, Bv1, Bv2, Ck, and Ccz horizons, between 47 and 155 cm depth. Total porosity (TP, % v/v) is medium and registers values of 46.5-47.7% v/v in the upper horizons down to 47 cm depth and low, 44.8-46.8% v/v, on the rest of the profile, between 47 and 155 cm depth. The soil is slightly settled on the 0-47 cm depth with compaction degree (CD, % v/v) values of + 0.5% v/v and moderately settled with a + 15% v/v value on the rest of the profile, between 47 and 155 cm depth. The values of the wilting coefficient (WC, % g/g) are very high, 15.5-18.6%, on the whole profile.

The field water capacity (FC, % g/g) is high, 25.5-26.3% g/g, down to 31 cm depth and medium, 21.6-24.7% g/g, on the rest of the profile, 31-155 cm depth. The maximum water holding capacity (MWHC, % g/g) is high with 30.5-33.2% values on the whole soil profile. The available moisture holding capacity (AWC, % g/g) is low, 7.1-10.8% g/g, down to 47 depth and very low, 3.7-5.1% g/g on the rest of the profile, on the 47-155 cm depth. Considering the variation range of the analyzed hydro-physical indicators values in correlation with soil structure state a less favorable hydric condition can be highlighted for plants growth and development, especially below 47 cm depth. Thus, the soil can't store high water quantities to put in readiness for plants because of its medium fine loamy-clayey structure, weak-moderate compaction degree, low available moisture holding capacity, high bulk density, and low total porosity.

Soil permeability for water (Ksat, mm/h) registers medium values, 2.95-9.82 mm/h, down to 130 cm depth and low, 1.77 mm/h, in the profile base between 130 and 155 cm depth, and correlates to the other hydro physical indicators. Soil resistance to penetration (RP, kgf/cm^2) is medium with 33-49 kgf/cm^2 values in the Ap, Apt, and Am horizons on the 0-47 cm depth and high with 53-67 kgf/cm^2 on the rest of the profile, between 47 and 155 cm depth.

Chemical characteristics. Soil reaction (pH) is slightly acid, 6.33-6.57, in the Ap, Apt, Am horizons down to 47 cm depth; neutral 7.12-7.20 in the A/B, Bv1, Bv2 horizons between 47 and 105 cm depth, and slightly alkaline, 8.04-8.19, in the Ck, Cca horizons, between 105 and 155 cm depth. Base saturation degree (V, %) is 88.6-90.6% in Ap, Apt horizons down to 31 cm depth and belongs to the eubasic range. The total cation exchange capacity (T, me/100 g soil) is medium, 30.68-32.58 me/100 g soil, on the whole profile. The sum of exchangeable bases (SB, me 100/g soil) is high, with 27.59-30.63 me/100 g soil values, the hydrolytic acidity (Ah, me/100 g soil) is low, 2.62-3.55 me/100 g soil down to 47 cm depth, in the Ap, Apt, and Am horizons, and very low, 1.29-1.95 me/100 g soil, on the 47-105 cm depth, in the A/B, Bv1, and Bv2 horizons.

The humus content (humus, %) is medium, 3.66-4.08%, in the Ap and Apt horizons and low, 3.42%, in Am, total nitrogen (Nt, %) supply is medium, 0.163-0.187%, mobile phosphorus (P_{AL}, mg/kg) is low - very low, 8-15 mg/kg on the 0-31 cm depth, the mobile potassium (K_{AL}, mg/kg) content is medium - high, 160-212 mg/kg. Calcium carbonate ($CaCO_3$, %) is medium, 2.6%, in the Ck horizon and high with a 12.8% value in the Cca horizon.

Biological characterization, performed through quantitative bacteria determinations ($NTBx10^6$/g dried soil) and fungi ($NTFx10^3$/g dried soil), highlighted low values. Only bacteria from non-sporogen genera are present: *Arthrobacter citreus, A. globiformis, Pseudomonas sp*. The autumn ploughing influence upon different microorganisms' groups reflects in more numerous fungi and mainly those of the *Fusarium* and *Aspergillus* genera proliferate. *Aspergillus nigeri* has the highest weight. It is possible that no organic matter of any kind, not even vegetal leftovers, were ever applied in the studied area so the microorganism's community was practically depleted, although the soil has a relatively good state from the chemical point of view.

The dynamics of the humus content in different soil tillage systems

Soil humus content increased on the 0-10 cm depth in the 54 months of experimentation when soil minimum tillage system was applied and registered a 4.62% value as compared to the conventional system where a lower value of 4.40% was registered (Figure 1). This is explained mainly by the large vegetal leftovers quantity remained at the soil surface, minimum 30% in the minimum working systems, and also by the balancing between mineralization and humification. Humus supply in the 0-30 cm layer was lower in the classic system because soil more intense mobilization favors a more rapid depletion of the humus accumulated over time, lower new humus synthesis, and soil organic matter mineralization enhancement (Figure 2). The lowest humus content, it was determined under 30 cm depth (Figure 3). Here the differences between minimum and conventional tillage are not relevant. Conservative tillage contributed to a certain extent to soil water supply and absorptive capacity increase through a slightly higher compactness state and especially through a higher humus content. A compaction/setting tendency is registered on a 10-15 cm depth in the first years of application on soils with broken-down structure.

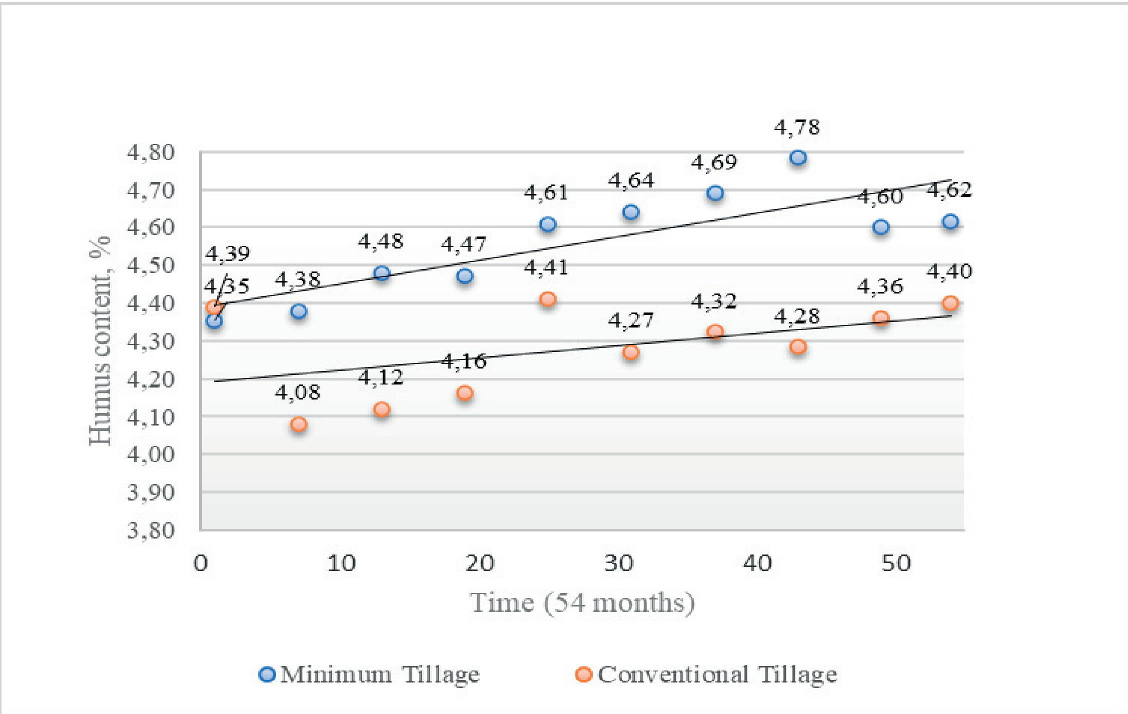

Figure 1. Evolution of the soil humus content depending on technology and time, on 5-10 cm depth

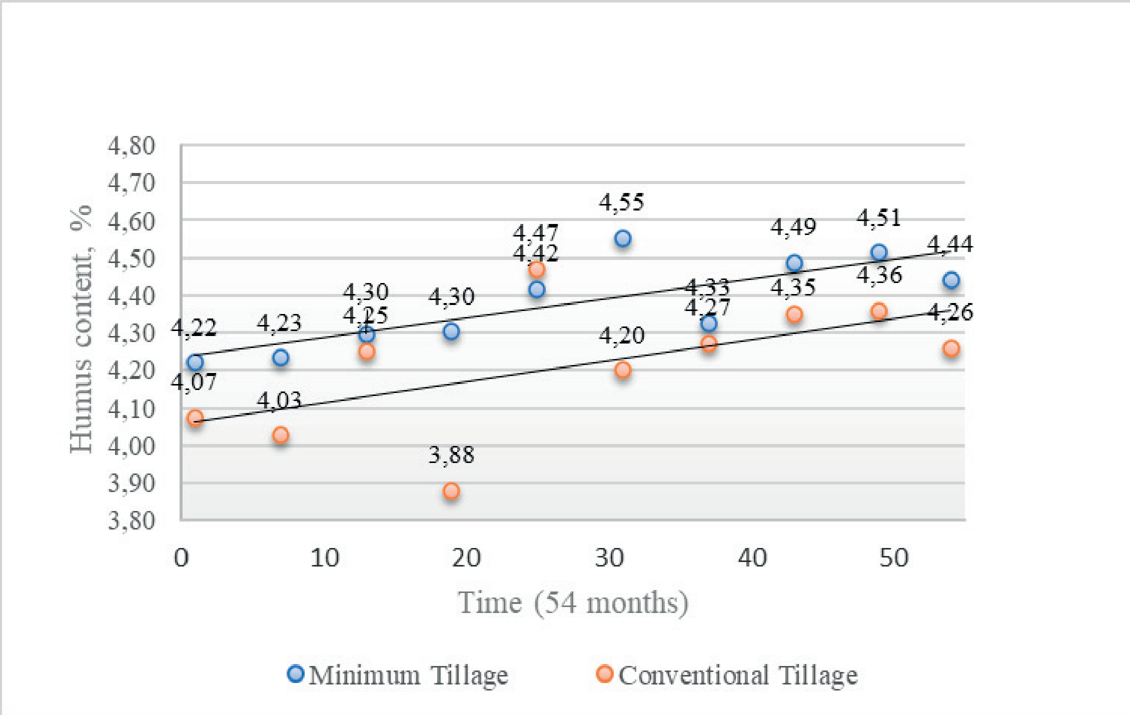

Figure 2. Evolution of the soil humus content depending on technology and time, on 25-30 cm depth

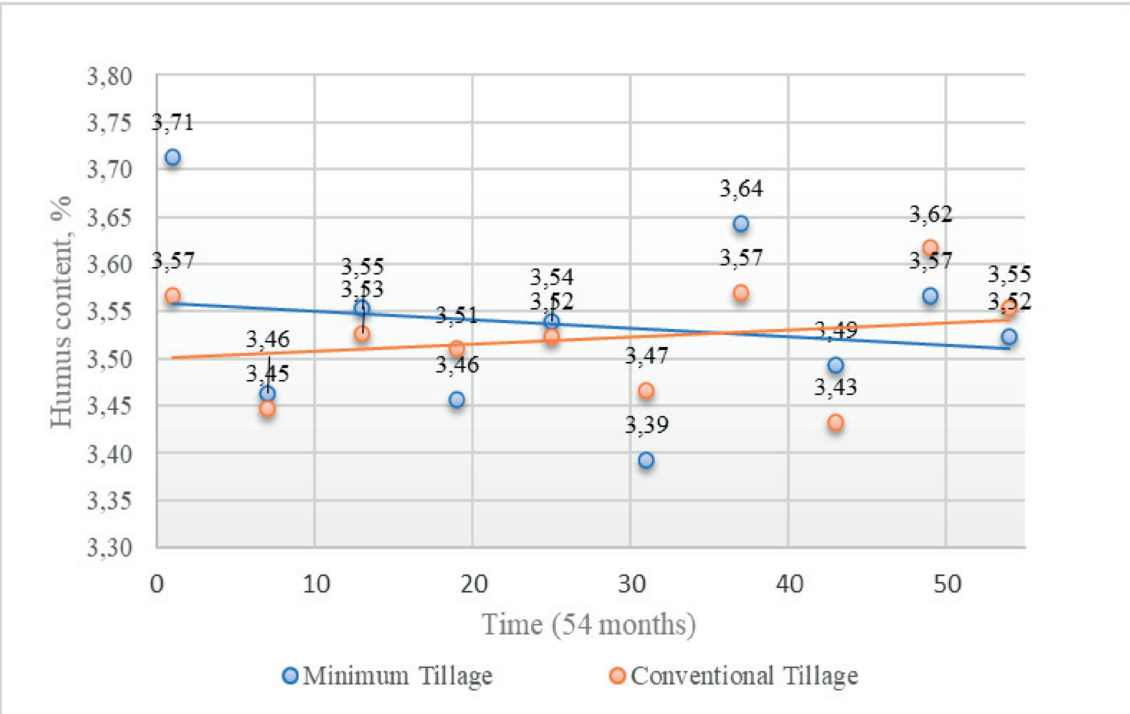

Figure 3. Evolution of the soil humus content depending on technology and time, on 45-50 cm depth

Soil humus content in the analyzed period registered higher values in the minimum tillage system on the 0-10; 0-30; and 0-50 cm sampling depths (Figure 4). On the 0-10 cm depth the humus content in the minimum tillage system registered a 4.43% value in the first year, as compared to 4.10% in the classic system, and in the fifth year 4.69% values as compared to 4.32%. On the 0-30 cm depth - 4.27% as compared to 4.14% in the classic system, 4.50% - 4.36% at the end of the experimentation. On the 0-50 cm depth 3.51% - 3.49%, and in the las experimental year the values were identical.

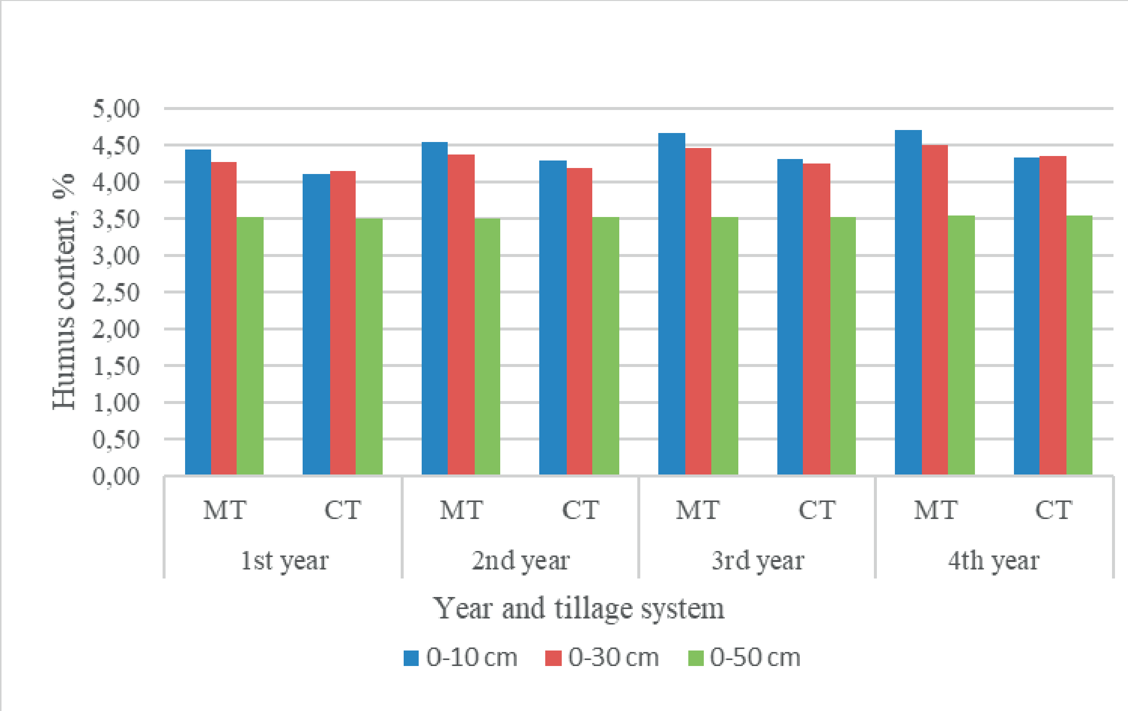

Figure 4. Humus content by depth, experimental years, and technology

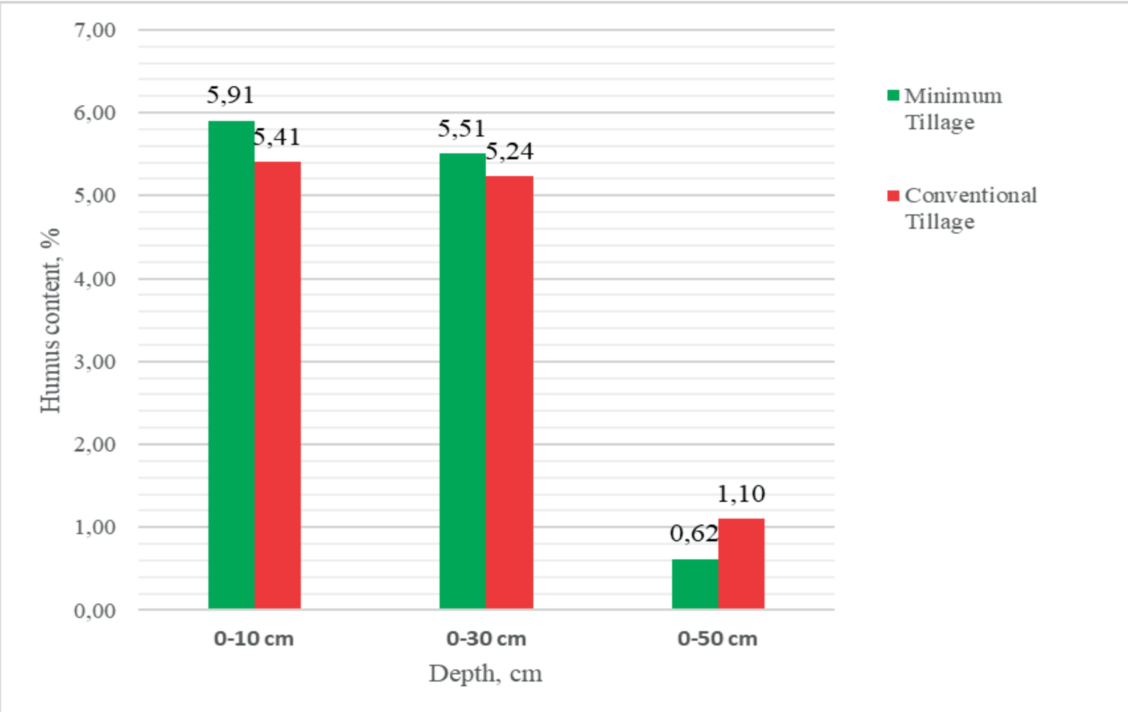

Figure 5. Humus content increase after the fourth experimental year depending on depth

Considering the small number of cultivars analysed in this study, future research will focus on a higher number of genotypes in order to validate the association of Hap II/ SNP-2606A with TKW. Also, the new allelic variant obtained with T7AM5 marker will be analysed for association with agronomical traits.

CONCLUSIONS

In the beginning of the experimentations the humus content was medium after which increases of the humus percentage were registered, especially in the upper layer (5-10 cm).

The evolution of the soil humus content through the application of different agricultural technologies was similar in all three studied depths, with increases in the case of minimum tillage system but without statistically significant differences as compared to the classic one. As a consequence, the different agricultural technological systems must assert, through their technological links, the growth and conservation of organic matter, i.e. the soil quality humus supply.

The soil organic carbon content increase is an excellent indicator of the effectiveness of a certain conservative agricultural practice considering its well-known agricultural and environmental benefits and its potential to mitigate climatic changes. Nevertheless, more research is needed and robust monitoring, audit, and reporting frame to exactly assess the organic matter gains and the way they are influenced and the rest of the physical, chemical, and microbiological properties.

Testing and applying new conservative agriculture technologies could contribute, in the long run, to improvement and prevention of the enhancement of physical processes specific to degradation of soils with fine loamy-clayey structure through compaction, cracking, and water excess.

The conservative agriculture has generally a positive impact upon agricultural crops yields because the increase of organic matter input in the system improves the water infiltration and storing capacities, soil nutrients availability, and increases microbiological activity.

ACKNOWLEDGEMENTS

This research was supported by the PN 23 29 03 01 project „*Managementul resurselor de sol în agroecosistemele afectate de aridizare în vederea menținerii biodiversității*” (*Soil resources management for preserving biodiversity in agroecosystems affected by aridization*), project number 44 PFE/2021, Program 1 - Development of national research-development system, Subprogram 1.2 - Institutional performance - RDI Excellence Financing Projects and SC Quality Crops Agro S.R.L.

REFERENCES

Abagandura, G., Mohamed Nasr, G.E.-D., Moumen, N.M., 2017. *Influence of tillage practices on soil physical properties and growth and yield of maize in Jabal Al Akhdar, Libya*. Open Journal of Soil Science, 7(7): 118-132. https://doi.org/10.4236/ojss.2017.77010

Aguilera, E., Lassaletta, L., Gattinger, A., Gimeno, B.S., 2013. *Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: A meta-analysis*. Agriculture, Ecosystems and Environment, 168: 25-36. https://doi.org/10.1016/j.agee.2013.02.003

Almagro, M., Garcia-Franco, N., Martínez-Mena, M., 2017. *The potential of reducing tillage frequency and incorporating plant residues as a strategy for climate change mitigation in semiarid Mediterranean agroecosystems*. Agriculture, Ecosystems and Environment, 246: 210-220. https://doi.org/10.1016/j.agee.2017.05.016

Biddoccu, M., Ferraris, S., Pitacco, A., Cavallo, E., 2017. *Temporal variability of soil management effects on soil hydrological properties, runoff and erosion at the field scale in a hillslope vineyard, North-West Italy*. Soil and Tillage Research, 165: 46-58. https://doi.org/10.1016/j.still.2016.07.017

Blanco-Canqui, H., and Ruis, S.J., 2018. *No-tillage and soil physical environment*. Geoderma, 326: 164-200. https://doi.org/10.1016/j.geoderma.2018.03.011

Burtan, L., Coronado, M., Vrînceanu, A., 2016. *Sisteme minime de lucrări ale solului*. Ed. Estfalia, Bucharest.

Çetin, M.D., 2021. *Investigation of agricultural properties of some cotton genotypes in second crop cultivation with two different tillages in Antalya*. Romanian Agricultural Research, 38: 215-221. https://doi.org/10.59665/rar3823

Chețan, F., Rusu, T., Chețan, C., Urdă, C., Rezi, R., Şimon, A., Bogdan, I., 2022. *Influence of soil tillage systems on the yield and weeds infestation in the soybean crop*. Land, 11(10): 1708. https://doi.org/10.3390/land11101708

Cizmaş, G., Cociu, A., Mandea, V., Marinciu, C.M., Şerban, G., Săulescu, N.N., 2022. *Wheat cultivar performance under no-till and traditional agriculture*. Romanian Agricultural Research, 39: 457-461. https://doi.org/10.59665/rar3943

Claassen, R., Bowman, M., McFadden, J., Smith, D., Wallander, S., 2018. *Tillage intensity and conservation cropping in the United States*. EIB-197, U.S. Department of Agriculture, Economic Research Service.

https://www.ers.usda.gov/webdocs/publications/90201/eib-197.pdf

Cociu, A., and Alionte, E., 2017. *Effect of different tillage systems on grain yield and its quality of winter wheat, maize and soybean under different weather conditions*. Romanian Agricultural Research, 34: 59-67.

Duda, B.M., Rusu, T., Bogdan, I., Pop, A.I., Moraru, P.I., Giurgiu, R.M., Coste, C.L., 2014. *Considerations regarding the opportunity of conservative agriculture in the context of global warmin*g. Research Journal of Agricultural Science, 46(1): 210-217.

FAO, 2023. *Conservation agriculture*. https://www.fao.org/conservation-agriculture/overview/what-is-conservationagriculture/en/

Florea, N., Bălăceanu, V., Răuţă, C., Canarache, A., 1987. *Methodology of pedological studies elaboration*. Institute of Pedological and Agrochemical Research Press, Bucharest. (In Romanian)

Florea, N., Munteanu, I., Rusu, C., 2012. *Sistemul român de taxonomie a solurilor - SRTS, Ediţia 2012*. Ed. Sitech, Craiova.

Francaviglia, R., Di Bene, C., Farina, R., Salvati, L., Vicente-Vicente, J.L., 2019. *Assessing '4 per 1000' soil organic carbon storage rates under Mediterranean climate: A comprehensive data analysis*. Mitigation and Adaptation Strategies for Global Change, 24: 795-818. https://doi.org/10.1007/s11027-018-9832-x

Francaviglia, R., Almagro, M., Vicente-Vicente, J.L., 2023. *Conservation agriculture and soil organic carbon: principles, processes, practices and policy options*. Soil Systems, 7(1): 17. https://doi.org/10.3390/soilsystems7010017

Gonzalez-Sanchez, E.J., Veroz-Gonzalez, O., Conway, G., Moreno-Garcia, M., Kassam, A., Mkomwa, S., Ordoñez-Fernandez, R., Triviño-Tarradas, P., Carbonell-Bojollo, R., 2019. *Meta-analysis on carbon sequestration through conservation agriculture in Africa*. Soil and Tillage Research, 190(July): 22-30. https://doi.org/10.1016/J.STILL.2019.02.020

Guș, P., and Rusu, T., 2011. *Sistemele neconvenţionale de lucrare a solului, alternative agrotehnice şi economice pentru agricultura durabilă*. Sisteme de lucrări minime ale solului, Al 6-lea simpozion cu participare internaţională, Cluj-Napoca, Romania.

Jităreanu, G., Ailincăi, C., Bucur, D., 2006. *Influence of tillage systems on soil phsical and chemical caracteristics and yield in soybean and maize grown in the Moldavian Plain (North-Eastern Romania)*. Soil Management for Sustainability, Germany, IUSS, Catena Verlag: 370-379.

Lal, R., 1997. *Long-term tillage and maize monoculture effects on a tropical alfisol in Western Nigeria. II. Soil chemical properties*. Soil and Tillage Research, 42(3): 161-174. https://doi.org/10.1016/S0167-1987(97)00007-X

Limon-Ortega, A., and Sayre, K.D., 2003. *Dry land wheat production on narrow raised beds; a promising option*. In: Palmier, L.R., Lo, A., Anaya-Gardũno, M., Mendoza, J., Rivera-Olivar, P., Figueroa Sandoval, B. (eds.), Proceedings of the XI International Rainwater Catchment Systems Assotiation Conference. Mexico D.F., Mexico: 590-604.

Mărin, N., Lupu, C., Șerban, M., Preda, C., 2021. *Long term nitrogen and phosphorus fertilization influence upon soil*. Romanian Agricultural Research, 38: 183-191. https://doi.org/10.59665/rar3820

Martínez-Mena, M., Perez, M., Almagro, M., García-Franco, N., Díaz-Pereira, E., 2021. *Long-term effects of sustainable management practices on soil properties and crop yields in rainfed Mediterranean almond agroecosystems*. European Journal of Agronomy, 123: 126207. https://doi.org/https://doi.org/10.1016/j.eja.2020.126207

Moroizumi, T., and Horino, H., 2002. *The effects of tillage on soil temperature and soil water*. Soil Science, 167(8): 548-559.

Nyakatawa, E.Z., Reddy, C.K., Sistani, K.R., 2001. *Tillage cover cropping and poultry litter effects on selected soil chemical properties*. Soil and Tillage Research, 58(2): 69-79. https://doi.org/10.1016/S0167-1987(00)00183-5

Pardo, G., del Prado, A., Martínez-Mena, M., Bustamante Muñoz, M.A., Rodríguez Martín, J.A., Álvaro-Fuentes, J., Moral, R., 2017. *Orchard and horticulture systems in Spanish Mediterranean Coastal Areas: Is there a real possibility to contribute to C sequestration?* Agriculture, Ecosystems and Environment, 238: 153-167. https://doi.org/10.1016/j.agee.2016.09.034

Peixoto, D.S., Montoani Silva, B., César de Oliveira, G., Guimarães Moreira, S., da Silva, F., Curi, N., 2019. *A soil compaction diagnosis method for occasional tillage recommendation under continuous no tillage system in Brazil*. Soil and Tillage Research, 194: 104307. https://doi.org/10.1016/j.still.2019.104307

Petcu, V., and Ciontu, C., 2014. *The effect of imidazolinone and tribenurom-methyl tolerant sunflower technology on weed control efficency and soil quality*. Lucrări Științifice, Seria Agronomie, 57(2): 53-57.

Petcu, V., Dincă, L., Toncea, I., 2014. *The effect of crops and farming systems on soil quality*. Scientific Papers, Series A, Agronomy, 57: 58-63. http://agronomyjournal.usamv.ro/pdf/2014/art10.pdf

Petcu, V., Ciornei, L., Simion, S.P., Grădilă, M., Burtan, S.L., Partal, E., 2022. *Cover crops from triticale and peas cultivated in pure stands and mixtures - soil and weed suppression benefits*. Romanian Agricultural Research, 39: 337-343. https://doi.org/10.59665/rar3931

Rusu, T., Guș, P., Bogdan, I., 2002. *Ileana, 2002 - Research regarding the conservation of soil fertility function of soil tillage systems*. Buletinul USAMV Cluj-Napoca, 57, ISSN 1454-2382.

Sheehy, J., Regina, K., Alakukku, L., Six, J., 2015. *Impact of no-till and reduced tillage on aggregation and aggregate-associated carbon in Northern European Agroecosystems*. Soil and Tillage Research, 150: 107-113. https://doi.org/10.1016/j.still.2015.01.015

Sîrbu, C., Cioroianu, T.M., Ionescu, N., Marin, N., Grigore, A., 2022. *Effectiveness of biostimulants applied to wheat, sunflower and soybean crops*. Scientific Papers, Series A, Agronomy, 1(65): 520-525. https://agronomyjournal.usamv.ro/pdf/2022/issue_1/Art76.pdf

Stavi, I., Bel, G., Zaady, E., 2016. *Soil functions and ecosystem services in conventional, conservation, and integrated agricultural systems. A review*. Agronomy for Sustainable Development, 36: 32. https://doi.org/10.1007/s13593-016-0368-8

Țopa, D., and Cuconoiu, C., 2017. *The influenence of soil compaction on roots development and yield*. Simpozionul Internațional "Universul Științelor", Iași, ISBN 978-606-576-722-5.

Țopa, D., Jităreanu, G., Ailincăi, C., Răus, L., 2013. *Impactul unor sisteme minime asupra producției și fertilității solului*. Ed. Ion Ionescu de la Brad, Iași.

Ulrich, S., Hofmann, B., Ticher, S., Olaf, C., 2006. *Influence of tillage on soil quality in a long-term trial in Germany*. In: Horn, A., Fleig, H., Peth, S., Peng, X. (eds.), Soil Management Sustainability. Cooperating Series of the International Union of Soil Science, Catena Verlag: 110-116.

Yadav, G.S., Datta, R., Pathan, S.I., Lal, R., Meena, R.S., Babu, S., Das, A., Bhowmik, S.N., Datta, M., Saha, P., Mishra, P.K., 2017. *Effects of conservation tillage and nutrient management practices on soil fertility and productivity of rice (Oryza sativa L.) - Rice system in North Eastern Region of India*. Sustainability, 9(10): 1816. https://doi.org/10.3390/su9101816