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The Main Physical and Chemical Characteristics of the Soil, Influenced by Conventional and Conservative Systems in Areas Susceptible to Aridification

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ABSTRACT

In this paper the influence of soil tillage on physical and chemical and characteristics of soil from different pedoclimatic areas from Romania was studied. Two soil tillage systems were experimented in Olt County, mostly in Iminog Plain, part of the Boian Plain: conventional (classical) and conservative (minimum tillage) at: Brebeni, Olt County; Adunații Copăceni, Giurgiu County; Constantin Brâncoveanu, Călărași County; and Roșiori, Brăila County. The identified soil classes in the area are Luvisols and Chernozems, with the types Haplic Luvisol and Haplic Chernozem (WRB-SR 2014). Soil samples were collected by 5-10; 25-30; and 45-50 cm depths and their physical and chemical properties were determined in the laboratory according to standardized methodology. Soil texture varied from coarse (silt loam) to fine (medium clay), no matter the soil tillage system. Other soil physical characteristics, such as resistance to penetration and total porosity showed slightly more favorable values in the conservative system. Soil chemical properties also varied. Soil reaction (pH) ranged from moderately acid to slightly alkaline and proved to be a bit more favorable for plants growth in the conservative system. Organic matter contents were very low - average, slightly better accumulating in the conservative system. Soil supply with nutritional chemical elements (nitrogen, phosphorus, and potassium) was very low - average for nitrogen and very low - high for phosphorus and potassium. Except for the potassium, which had better values in the conservative system, no significant differences were noticed between the two soil tillage systems. Soil cation exchange properties framed the samples in the oligomesobasic - eubasic classes. Samples of the conservative system generally had a better base saturation degree. Although soil physical and chemical characteristic in the investigated plots differ relatively little between the working systems slight improvements are noticed from these points of view when minimum tillage technology is applied. It is to be predicted that constant and consistent application of conservative technologies will bring about better soil fertility properties preservation and even their improvement.

Keywords: aridization, reduced till and inversion tillage, soil physical properties, soil chemical properties.

INTRODUCTION

Deteriorating soil health poses a global challenge in the context of food insecurity, climate change and environmental degradation (McBratney et al., 2014; Ciornei et al., 2023). Soil is an asset for agricultural systems; it is also a global sink for carbon. Soil health is diminished through loss of soil itself by erosion, and by loss of soil carbon, organic matter and nutrients. Agriculture is a key driver of global soil erosion (Montgomery, 2007), with an estimated reduction of some 0.3% of production per year globally (Den Biggelaar et al., 2003; Prety and Bharucha, 2014). In recent decades, there has been much research into the analysis of the relationship between climate aridity and land degradation, as well as their contribution to desertification from the perspective of climate change. Once plant residues increase water infiltration into the soil and reduce evaporation, more water is available to plants in Conservative Agriculture (AC). In areas with dry climates, where intensive soil tillage and removal of plant debris contribute to the loss of soil water, thus intensifying the processes of drought, aridification and implicitly desertification (Burtan et al., 2023). A variety

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of measures to mitigate soil erosion, improve water-holding capacity and increase soil organic matter help to improve soil health and boost crop yields. A key feature is the revision or reduction of soil disturbance through tilling. Zero tillage involves no ploughing prior to sowing.

Conservation agriculture consists of a group of management strategies to minimize soil disturbance, maintain soil cover and rotate crops. This seeks to maintain an optimum environment in the root zone in terms of water availability, soil structure and biotic activity (Kassam et al., 2009). Conservation tillage is a term encompassing many different soil management practices. One commonly used definition (Mannering and Fenster, 1983) is "any tillage system that reduces loss of soil or water relative to conventional tillage; often a form of non-inversion tillage that retains protective amounts of residue mulch on the surface". Soil management practices, such as conservation tillage, that minimize tillage and improve physical properties and soil carbon are alternatives to conventional soil management that uses aggressive tillage (Pretty and Bharucha, 2014; ABS, 2018; Matei et al., 2024). For a crop production system to be widely accepted, it must maintain the soil's physical quality. Soil physical factors that influence water infiltration and soil erodibility include organic matter content, aggregation, porosity, and density (Blevins and Frye, 1993). Additionally, crop rotations can improve the sustainability and productivity of cropping systems (Bowles et al., 2020). Crop rotation and tillage can also improve soil physical properties (Hulugalle and Scott, 2008; Somasundaram et al., 2018), infiltration, soil water storage, crop water use efficiency (Basche and DeLonge, 2019), and soil biological properties (Palmer et al., 2023). Sustainable agricultural activity must be organized in a system, scheduled in a sequence and always analyzed as part of the relationship: soil-plant-climate area-socio-economic conditions-crop-efficiency (Wang et al., 2008; Bucur et al., 2011; Afzalinia et al. 2012; Domuta et al., 2012; Rusu, 2014).

MATERIAL AND METHODS

Intensive soil processing frequently has a negative impact on the physical and chemical quality of soil in aridized regions. This study aimed to assess the soil physical and chemical characteristics and the availability of nutrients in two different systems of soil tillage: conventional and conservative (minimum tillage).

Pedoclimatic characterization of the studied areas:

Brebeni, Olt County, geographic coordinates: N 44.40928; long: E 24.48699. Most of the territory belongs to the Iminog Plain, Boian Plain sub-unit. Micro depressions and dells fragmenting the cliffs are to be met as micro relief forms. Multi annual average temperature is 10-11°C (annual average) and varies from -1.7°C (monthly average) in January, the coldest month of the year, to 22.1°C in July, the hottest one. Rainfall annual average amounts to 519 mm, the poorest moth is February (25.6 mm) and the rainiest is June (99.5 mm). The Brebeni Commune territory belongs to the transition zone from forest steppe to forest (oak level). Woody species occur such as *Quercus robur*, *Quercus cerris*, *Quercus frainetto*, *Prunus spinosa*, *Tilia sp*., *Acer campestre*, *Fraxinus excelsior*. In the meadow area *Populus alba*, *Alnus glutinosa*, *Salix fragilis occur*. Of the herbaceous species *Setaria viridis*, *Cynodon dactylon*, *Convolvulus arvensis*, *Polygonum aviculare* can be mentioned. The representative soil type of the body is Haplic Luvisol (WRB-SR 2014) with a medium clay loam - loamy clay structure.

Adunații Copăceni, Giurgiu County, geographic coordinates: N 44.21631; long: E 26.07752. From the geo-morphological point of view the body is part of the Romanian Plain. From the relief point of view its main characteristic is typical smooth plain. The climate is temperate continental. Average temperatures of the summer months have values between 20.4 and 23.2°C and the maximum ones reach 38.7°C. Winters are cold as influenced by the east continental and arctic cold air masses, with many frosty days. Monthly average temperatures range from +0.3 to -3.2°C and those of the monthly average minimums between -1.5 and -16.4°C. There are long drought durations due to low rainfall in summer months, when evapotranspiration manifests itself, which determines a significant humidity deficiency sometimes strongly felt by cultivated plants. Vegetation belongs to forest steppe consisting of oak forests and herbaceous vegetation. The representative soil type is Haplic Luvisol (WRB-SR 2014) with a medium loam - medium clay loam texture.

Constantin Brâncoveanu, Călărași County, geographic coordinates: N 44.49972; long: E 27.40214. The studied area belongs to the Romanian Plain, Bărăganul Ialomiței sub-unit. The climate is moderately continental. Annual average temperature is 10.7°C. The hottest months are July with 22.2°C and August with 21.9°C. The month with the lowest temperature is January: -22°C, followed by February. Maximum 40.9°C and minimum 20.6°C summer temperatures show the climate specific continental character. Annual rainfall average is 552.4 mm. The vegetation mostly belongs to the steppe area once characterized by grasslands consisting of: *Poa bulbosa*, *Stipa capillata*, *Artemisia austriaca*, *Euphorbia stepposa*, *Festuca valesiaca*. The representative soil type is Haplic Chernozems (WRB-SR 2014) with a medium loam texture.

Roșiori, Brăila County, geographic coordinates: N 44.84115; long: E 27.383945. The territory belongs to the Middle Bărăgan sub-unit. The climate is moderately continental with more temperate shades in the Siret Meadow. Yearly rainfall is low, 450 l/m^2 on an average. The plain belongs to the subarid zone in which steppe grasslands dominate with *Festuca valesiaca*, *Stipa capillata*, *Dilpachne serotina*, *Artemisia austriaca*, *Agropyron cristatum associations*. On strongly salinized areas halophile plants frequently occur such as: *Suaeda maritima*, *Salicornia herbacea*, *Salsoda soda*, *Bassia sp*. The unit's representative soil type is Haplic Chernozem (WRB-SR 2014) with a sandy silt loam - sandy silt texture.

Soil sampling

Two main soil profiles have been performed and characterized from the morphological point of view and the physical and chemical characteristics, according to the Working Methodology of ICPA Bucharest (MESP, vol. I-III, 1987). Soil samples were collected on the 5-10 cm; 25-30 cm and 45-50 cm depths). The analyses and determinations carried out are in accordance with the methodology and STAS in force (SRTS, 2003).

Physical analysis:

Granulometric composition, according to the pipette method for fractions <0.02 mm, inclusive; wet and dry sieving method for fractions and subfractions included in the range 2-0,02 mm. The bulk density (Dawi) was determined by the pycnometer method, it is expressed in g/cm^3. Total porosity (PT) is expressed in % by Volume (%v/v) and was determined using the formula:

$$PT = \left(1 - \frac{DA}{D}\right) \cdot 100$$

in which: the numerical values of the bulk density were obtained from soil samples taken in metal cylinders with known volume (100 or 200 cm^3), and for the soil density the numerical value 2.68 g/cm^3 was used.

The standard penetration resistance (RD) was determined in the laboratory, using the dynamic penetrometer, at a soil moisture of 50% of the total water capacity; it is expressed in kgf/cm^3.

Chemical analysis:

pH, nitrogen, phosphorus, potassium. Determination of pH was carried out in 1:2.5 water suspension; humus content (%) was determined by wet oxidation (Walkley-Black method, modified by Gogoașă); nitrogen content (Nt%) was determined by the Kjeldahl method; mobile phosphorus (P_{AL}) and potassium (K_{AL}) contents, available for plant nutrition, were extracted in ammonium acetate-lactate solution at pH 3.7 and determined by flame photometry (potassium) and UV_VIS spectrometry (phosphorus).

RESULTS AND DISCUSSION

The results presented in this paper were obtained in a one-year experiment in areas affected by aridification, on soils with different textures and two tillage systems.

Influence of tillage systems on the soil chemical properties

Soil reaction (pH) in the four studied areas on the 5-10 cm depth varies from moderately acid (5.08) at the soil sampling point in the Brebeni area to weakly alkaline (8.03) in the Roșiori area. The same situation is encountered on the following sampling depths (25-30 cm and 45-50 cm). These differences are due to the calcium carbonate ($CaCO_3$) content which is a defining characteristic for chernozem.

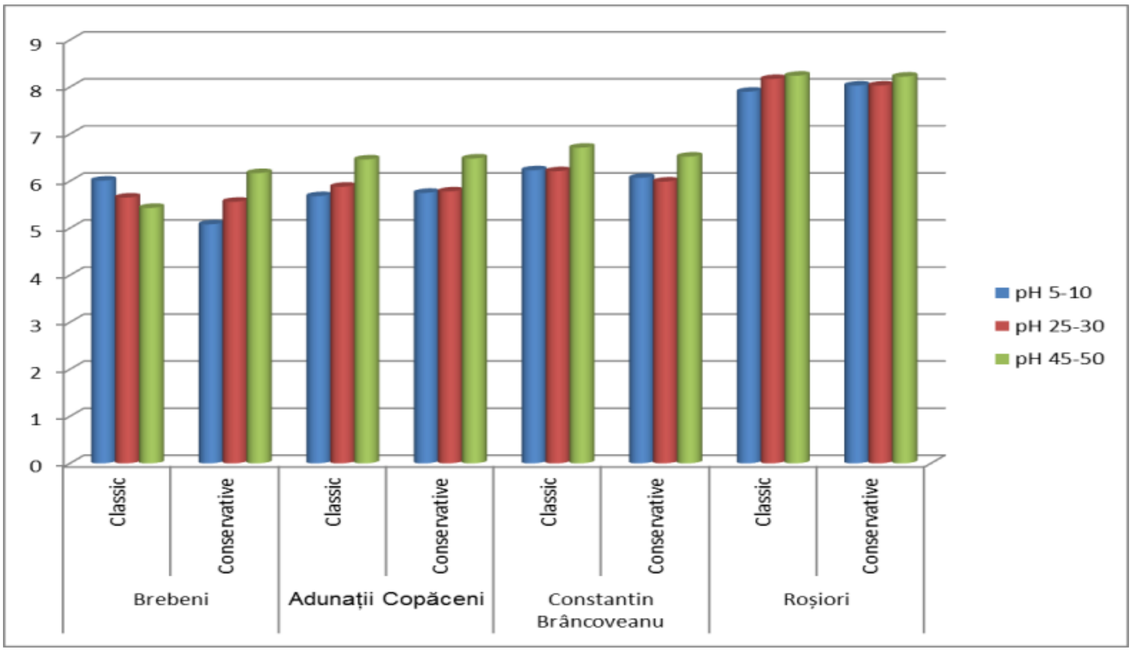

Figure 1. Soil reaction in the studied areas

Humus content on the 5-10 cm depth is small in the classical system (conventional) and medium in minimum tillage in all studied fields, except for the Copăceni area, where the organic matter content is small (2.68-2.62%) in both systems. In the first experimental year the average content of organic matter in minimum tillage is due to the preservation of plant residues at the soil surface. On the 25-30 cm sampling depth of the Roșiori area the organic matter content is medium, with a 2.78% value in the minimum tillage system and 2.25% in the classical one. For the areas of Brebeni, Copăceni and Constantin Brâncoveanu, the organic matter content is small in both systems. On the last sampling depth (45-50 cm) the amount of organic matter decreases in all four areas.

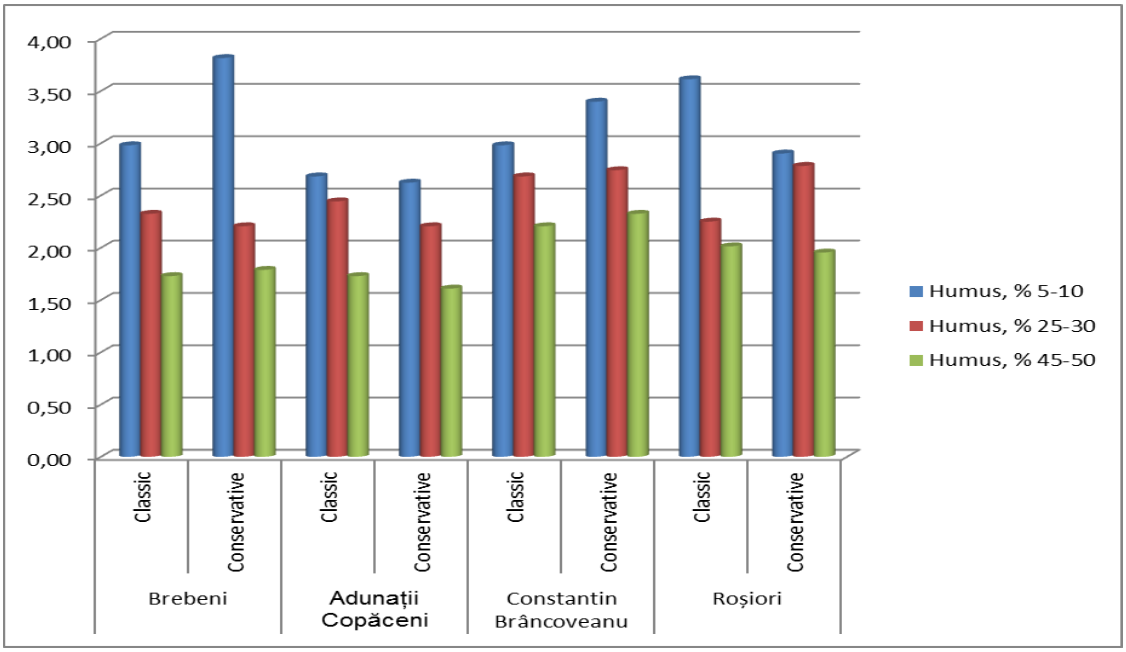

Figure 2. The dynamics of the humus content in different soil tillage systems

Total nitrogen content (Nt%) in experimental fields organized on the same soil type (Haplic Luvisol (WRB-SR 2014), at Brebeni and Copăceni, is medium (0.160%) in minimum tillage (Brebeni) on the 5-10 cm depth. On the following depths (25-30 cm and 45-50 cm) the supply degree varies from very small to small (0.080%-0.124%) in both soil tillage systems. On the second type of soil, Haplic Chernozems (WRB-SR 2014), in the Constantin Brâncoveanu and Roșiori areas, the nitrogen content values are similar (medium-small), except for the 5-10 cm depth in the field with minimum tillage from Roșiori, where a very small value is highlighted (0.050%). Soil samples were taken during the plants vegetative growth period which explains the values of total nitrogen content.

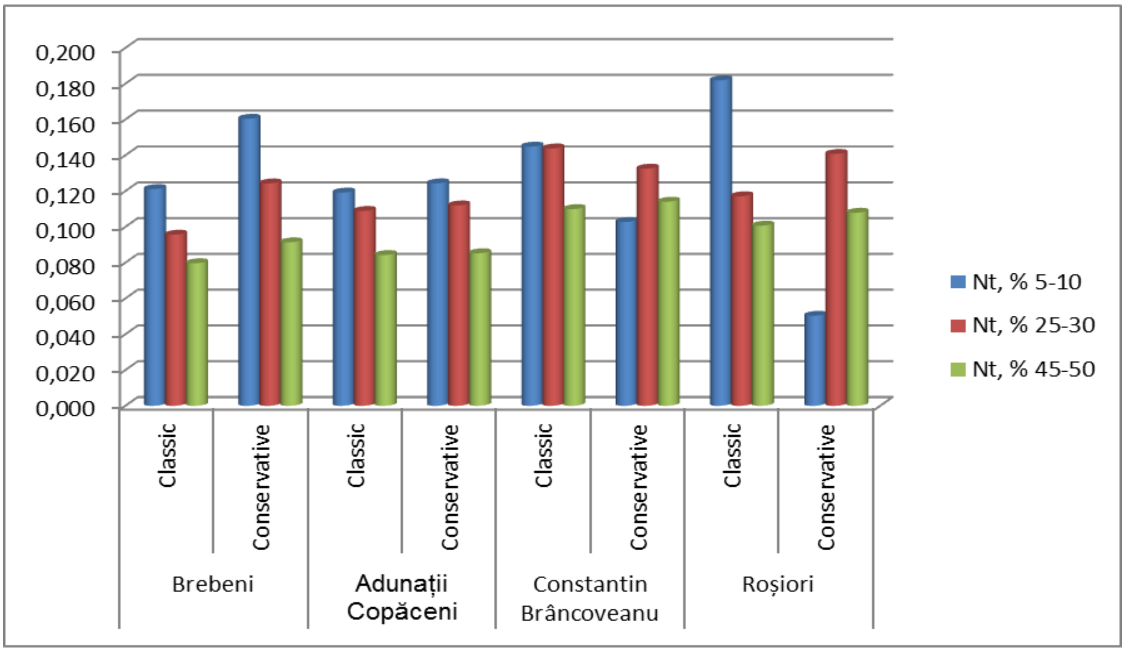

Figure 3. The dynamics of the total nitrogen content in different soil tillage systems

Mobile phosphorus content (P_{AL} mg/kg) in the Haplic Luvisol from the Brebeni area varies with the depth in both soil works systems. The highest value in the conventional system (61 mg/kg) is to be met on the 5-10 cm depth and in the minimum tillage the supply is medium (31 mg/kg). In Copăceni area the supply degree is high on the first two depths (55-45 mg/kg) in both systems, and at the 45-50 cm depth a medium content is noticed (21 mg/kg) in conservative and small (18 mg/kg) in conventional system. In the other soil type, Haplic Chernozem (WRB-SR 2014), in Constantin Brâncoveanu and Roșiori areas, the mobile phosphorus supply degree is high (56 mg/kg) on the 5-10 cm depth, in the conventional system at Roșiori, as for the rest it oscillates at medium - small - very small values regardless of sampling depth, working system, or area.

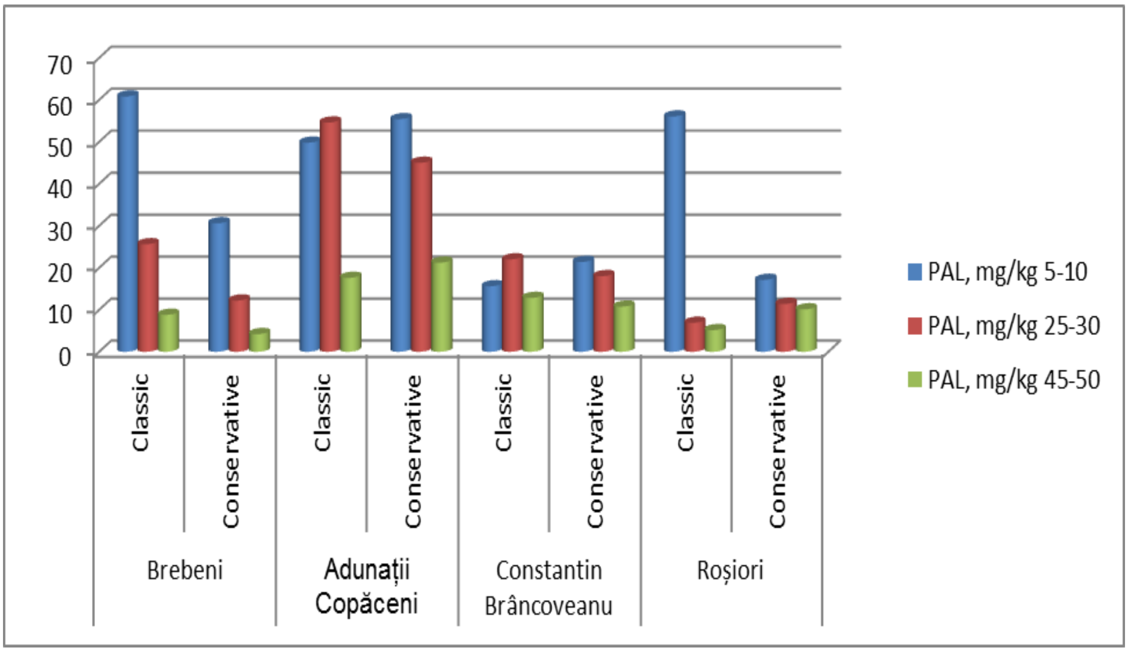

Figure 4. The dynamics of the phosphorus mobile content in different soil tillage systems

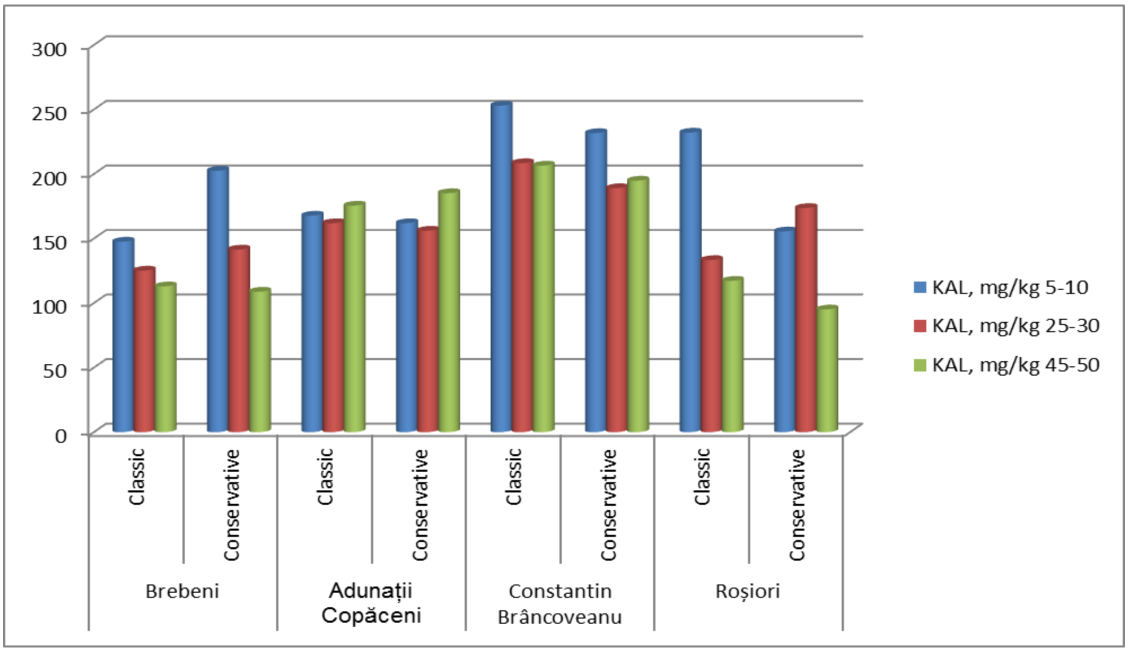

Figure 5. The dynamics of the potassium mobile content in different soil tillage systems

The content of mobile potassium (K_{AL} mg/kg) in Haplic Chernozems in the conventional system is high on the 5-10 cm depth in Constantin Brâncoveanu and Roșiori areas with values of 253 mg/kg and 232 mg/kg respectively, as compared to the Haplic Luvisol where there are medium values of mobile potassium supply, except for the field with minimum tillage works (Brebeni) with a high value of 203 mg/kg. On the following soil sampling depths the mobile potassium content decreases with the depth regardless of the soil type or the studied area, the exception is the Constantin Brâncoveanu area in the conventional system, where high values are recorded (208 - 206 mg/kg).

Rotation crops within cropping systems can alter the nutrient distribution of the soil profile depending on their rooting depth and crop demand (Houx et al., 2014; Armstrong et al., 2019) beyond the tillage depth in the profile.

Influence of tillage systems on the physical properties

Bulk density (Dawi g/cm^3) of the Haplic Luvisol in the organized fields differs between the two soil works systems on the first sampling depth.

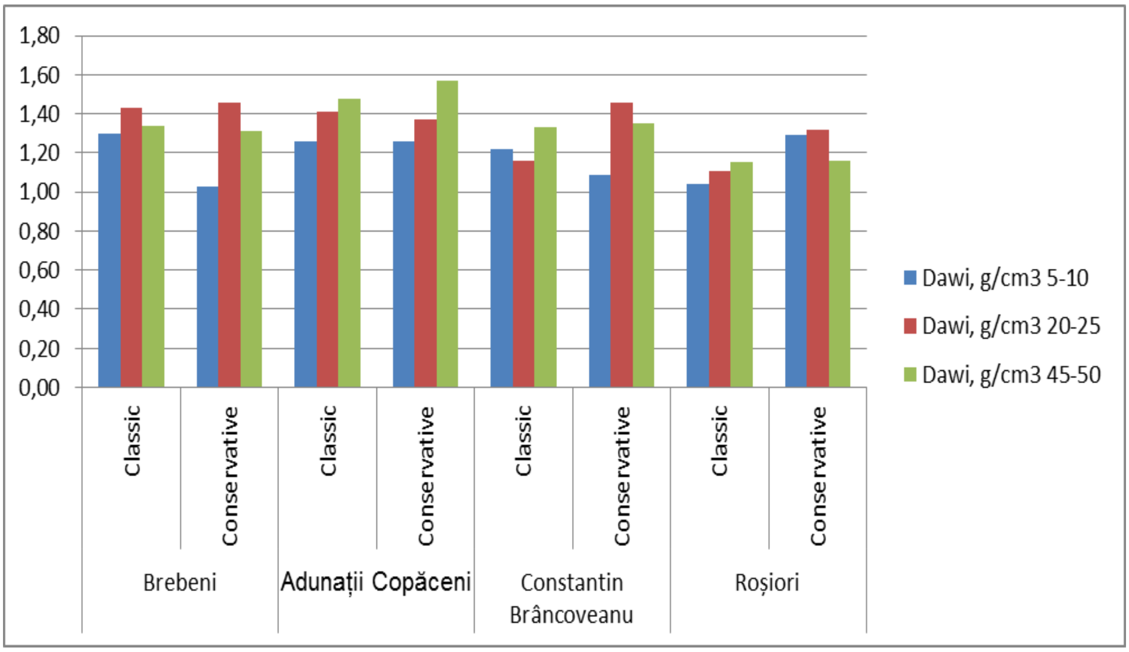

Figure 6. Bulk density in soil under conventional and minimum tillage systems

The bulk density (Dawi g/cm^3) of the Haplic Luvisol is different between the two systems of soil works in the first sampling depth of 5-10 cm in the field organized at Brebeni, the soil is unattached (1.30 g/cm^3) in the conventional system and on the following depths the soil is poorly tamped. In minimum tillage at 5-10 cm depth the soil is very loose (1.03 g/cm^3) and moderately tamped (1.46 g/cm^3) at 25-30 cm and poorly tamped at 45-50 cm (1.31 g/cm^3) (Figure 6). Although the soil texture is clay loam which represents a limiting factor regarding the suitability to conservative agriculture, it is noted that this system of works brought an improvement in bulk density over conventional agriculture. In the Copăceni field the soil texture is medium clay and there is no difference between the two systems. In the experimental field organized at Constantin Brâncoveanu the bulk density is different in both systems at all depths. If in the conventional system the soil is loose (1.22 g/cm^3 - 1.16 g/cm^3 - 1.33 g/cm^3) in the conservative one (minimum tillage) the soil is very loose, with a 1.09 g/cm^3 bulk density value, poorly tamped (1.46 g/cm^3) and loose (1.35 g/cm^3) at the last depth. In Roșiori there is the same situation as in the case of Constantin Brâncoveanu. In both conventional and conservative systems the soil structure is silt sandy loam. If in the conventional system the values are extremely low at all three depths (1.04 g/cm^3 - 1.11 g/cm^3 - 1.15 g/cm^3), in minimum tillage the soil density increases on the first two depths (1.29 g/cm^3; 1.32 g/cm^3) and at the last depth the bulk density is extremely low (1.16 g/cm^3) (Figure 6).

The penetration resistance (RP kgf/cm^2) in the Brebeni experimental field is the same in the two systems except for the minimum tillage system at the first sampling depth (17 kgf/cm^2) where small values are noticed (Figure 7). Penetration resistance increases with depth in the field under conventional technology in the Copăceni field, is medium under conservative technology at the first two depths and large at the 45-50 cm depth. At Constantin Brâncoveanu the values of this indicator are similar in the first 5-10 cm soil layer for both technologies and increases in depth. The obtained results revealed a higher penetration resistance under minimum tillage as compared to the classical system in the Roșiori field.

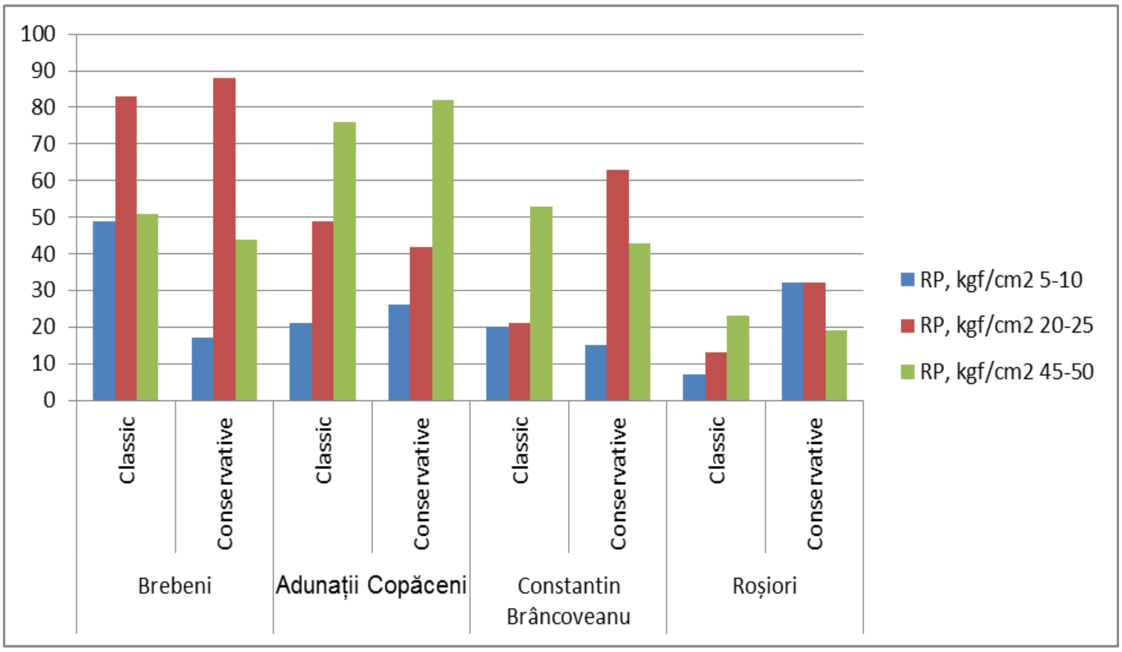

Figure 7. Soil penetration resistance under conventional and minimum tillage systems

The total porosity (PTwi, % v/v) in the Brebeni field is different: if in conventional soil aeration is moderately deficient (50.9% v/v) at the 5-10 cm depth, in minimum tillage (conservative) the soil is moderately aerated (61% v/v) and at the following depths soil aeration is deficient or moderately deficient in both technologies (Figure 8). In contrast to Copăceni, the total porosity of the soil is similar in both soil works technologies. On the Constantin Brâncoveanu Haplic Chernozem the soil aeration is identical of in both technologies except for the 25-30 cm depth, where it is moderately deficient. On the sandy loam texture from Roșiori the soil is excessively aerated under conventional technology at all depths (60.6% v/v; 58.1% v/v¸ 56.5% v/v) While under minimum tillage the first two depths meet an optimal (51.3% v/v; 50.1% v/v) and a moderate aeration (56.3% v/v) at 45-50 cm.

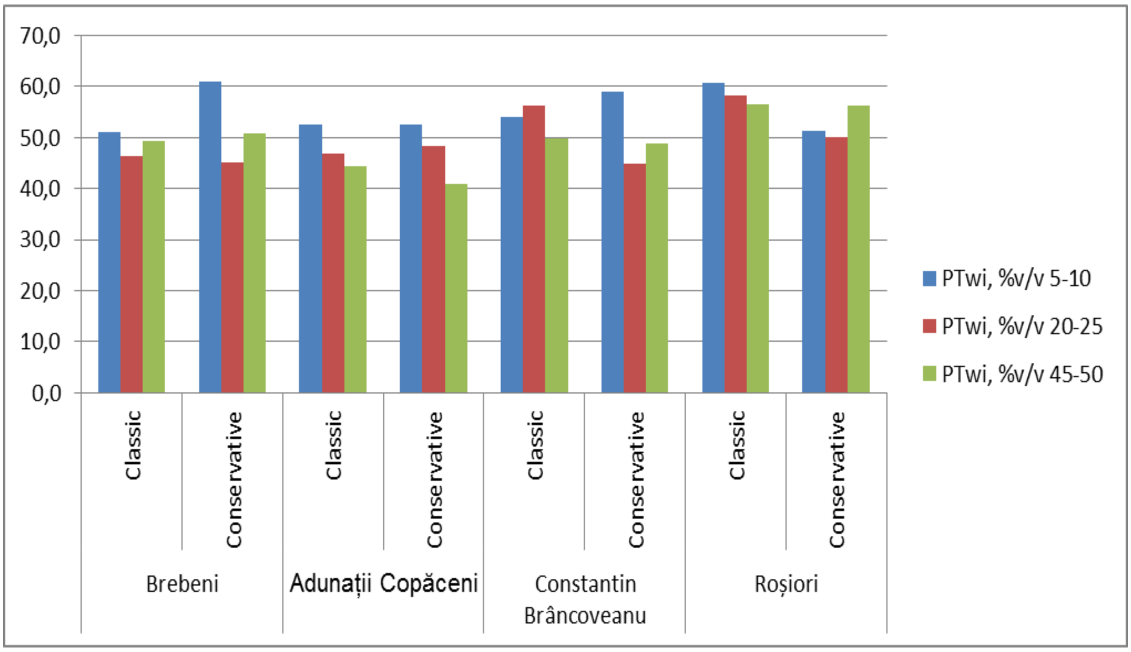

Figure 8. Influence of tillage systems on soil porosity

CONCLUSIONS

For the two experimental fields organized in the Brebeni area the structure is medium at the first two sampling depths and fine at the last one, which does not affect the long-term transition to conservative agriculture. Superimposed, the two structure types (medium and fine) in the Copăceni field make the physical characteristics less and less favorable, as a result of the increase in clay content. In literature it is recommended to perform a scarification (deep work) every 3-4 years, without mobilizing the bio accumulative horizon. A difference occurs in the first experimental year in the Roșiori area between the two technologies of soil works from the point of view of physical characteristics. The medium texture and stable granular structure of the Constantin Brâncoveanu experimental field ensure a good aeration and good permeability for water and air, a good capacity of retaining useful water and a lower resistance to soil works. All the indicators characterized highlight, on one hand, the fact that the soil is suitable for conservative works, and on the other that there is a risk of intensification of degradation through the continuous application of conventional agriculture.

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