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THE INFLUENCE OF TILLAGE SYSTEMS ON SOIL COMPACTION IN THE CORN CROP

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ABSTRACT. During the last decades, no-tillage has started to be used on more and more areas, being a conservative tillage system practiced in many farms in the country. The aim of this study was to quantify the effects of the no-tillage system on the physical properties of the soil compared to the conventional system, in a plateau area with cambic chernozem soil under the current climatic conditions in the north-east of Romania, in order to implement it in agricultural practice of the studied area. The soil samples were taken in natural and undisturbed conditions for bulk density and moisture content, soil penetration resistance was determined using the Eijkelkamp penetrologger. The status of soil compaction, the various porosity categories, and the soil moisture content were all determined based on field and laboratory analysis. Measurements performed at a depth of 0-40 cm showed a lower bulk density in the conventional system, and in terms of variation in values from sowing to harvesting, there was a maximum increase of 18% in the 10-20 cm soil layer, an intermediate of 10% in the topsoil and 20-30 cm layers, and a minimum of 1% in the 30-40 cm layer. Total porosity, which reflects soil pore volume, is inversely correlated with bulk density, which means that under conventional tillage practices, soil macropore volume (>0.05 cm) was higher (47.79-60.82% v/v) than under no-tillage practices (45.90-50.79% v/v) for 0-40 cm depth at the sowing time. The results confirm that the no-tillage system conserves more water in the soil under current climatic conditions.

Keywords: no-tillage; conventional tillage; soil physical properties.

INTRODUCTION

Global research on conservative systems provides several insights into the impact of these types of agricultural systems on the farming environment, with their effects being different from one area to another, influenced in particular by soil and climatic conditions. Regional studies on this topic are needed, because studies around the world cannot provide a general solution (Alskaf *et al.*, 2020; Crittenden and de Goede, 2016).

Since the 19th century, anthropogenic activities have caused an increase in average temperature of 0.9°C, primarily as a result of greenhouse gas (GHG) emissions into the atmosphere. According to estimates, this increase is expected to reach 1.5°C by 2050 or even higher (Naveen *et al.,* 2019). As a consequence of these changes, more water is lost from the soil due to higher average temperatures, making it necessary to improve agricultural technologies to retain a higher content of water in the soil.

Compaction-related soil degradation is a growing issue as agricultural machinery's power and mass continue to rise, which has been a trend for the past 30 years (Antille *et al.*, 2015). The detrimental effects of compaction on soil porosity and pore functionality, specifically air permeability, have been widely investigated (Alaoui *et al.*, 2011; Zhai and Horn, 2019a, b).

Soil compaction caused by heavy traffic of agricultural machinery in conventional tillage is a well-known problem today. Adopting specific agricultural equipment in the conservation tillage system, especially in maize cultivation, solves many problems in today's agriculture. As a result, the soil conditions, air circulation, water circulation and water retention are maintained or improved (Pleskachev *et al.*, 2021). When repeated passes with machines are performed on the same soil, the negative effects of compaction increase and may extend into deeper layers (Pulido-Moncada *et al.*, 2019; Schjønning *et al.*, 2016). Soil compaction leads to a decrease of the total pore volume, an increase of bulk density and penetration resistance, and a change of soil condition in a way that affects all processes of the soil mass with an intensity equal to the level of compaction. The intensity of anthropogenic compaction can be amplified by some soil characteristics, machinery systems and farming technologies (Jităreanu *et al.*, 2020).

Studies of soil hydro-physical indicators found that they were not significantly influenced by short-term tillage systems (no-tillage, minimum tillage, and conventional tillage). The soil compaction indicators as compression degree (CD) and bulk density (BD) had the lowest value in the variant with ploughing, a medium value in the variant without turning the furrow, and the minimum values in no-till (Răus *et al.*, 2016).

The physical quality is an important concept to describe the condition of a soil, the state of its degradation, and the impact of tillage systems applied worldwide on soil functions (Valle *et al.*, 2018). Soil physical quality is influenced by soil structure, the structure of the pore system and its continuity over depth (Rabot *et al.*, 2018). Reducing the number of passes with agricultural machines is one of the main agrotechnical methods for improving physical properties, increasing the water content of soil aggregates and the stability of the soil structure (Song *et al.*, 2019).

An important parameter being increasingly used to indicate soil compaction status is bulk density (Valle *et al.*, 2018). Even though this parameter does not describe the functionality of pores and the pore system, it is used all over the world to determine soil compaction status due to the fact that it is an easily measured physical property (Hartge and Horn, 2016).

The tillage system with furrow turning has contributed to increased bulk density values, but they are below critical values that can affect crop growth and development (Țopa *et al.*, 2021).

One of the main aim of a conservation tillage system is to increase drought resistance (Andrzej *et al.*, 2014, Ghaley *et al.*, 2018, Moraru *et al.*, 2015). According to some studies, conservative tillage systems (zero tillage system) lead to higher bulk density and penetration resistance compared to conventional tillage systems (Afzalinia *et al.*, 2014).

This study's main goals were to summarize the effects of no-tillage on soil physical properties and describe how environmentally friendly the practice is. The specific objectives were to investigate the impact of tillage systems on soil bulk density, penetration resistance, porosity and water content. The results of this study will be of value to farmers from the north-east of the country, as the no-tillage system, in addition to its beneficial effects on the physical condition of the soil, leads to optimised farm management by reducing the number of mechanical passes in the field, using less machinery and farm equipment, reducing labor requirements and therefore reducing production costs.

MATERIALS AND METHODS

In this study are presented some of the results obtained on the experimental field of the Department of Soil Management, during 2021-2022 agricultural year, at the Ezăreni farm ($47^o07'$ N latitude, $27^o30'$ E longitude), which belongs to Iasi University of Life Sciences. From a geo-morphological point of view, the farm is located in the transition coast of Iasi, in a plateau area, with cambic chernozem soil and a clay-loam texture (SRTS, 2012).

Two tillage systems formed the basis of the field experiment: conventional (CT), with ploughing at 30 cm and no-tillage with direct seeding (NT) with Fabimag FG – 01 seed drill (*Figure 1*). Each system has 4 plots, with an area of 2 ha (20.000 m^2) for each crop in the rotation.

Figure 1 – Maize sowing with Fabimag FG-01 seed drill

The experiment started in 2014; in the no-tillage system the soil hads not been tilled for 8 years. Since then, a crop rotation with winter wheat, maize, sunflower and peas has been cropped. Before the experiment, the land was tilled conventionally throughout. The maize crop hads two plots, one for each cropping system and was planted on 27 April 2022 (*Figure 2*). During maize cultivation, the activities carried out with agricultural machinery for both tillage systems consisted of two passes to carry out phytosanitary treatments, the first at the end of June and the second two weeks apart. The area of conventional tillage and no-tillage are the same since the beginning of the experiment and the slope of the land is similar. Under NT treatment, the maize residues were chopped into 2 – 4 cm long pieces and left at the soil surface after the maize was harvested with a combine harvester (model: New Holland TC 5050).

The specific climate of the area is temperate-continental, with an average precipitation of 691.8 mm and 432.8 mm in 2021 and 2022, respectively (*Figure 3*), and an average annual temperature of 10.8 °C, data recorded by Ezăreni weather station.

Figure 2 – The experimental plots - Ezareni farm in north-eastern Romania

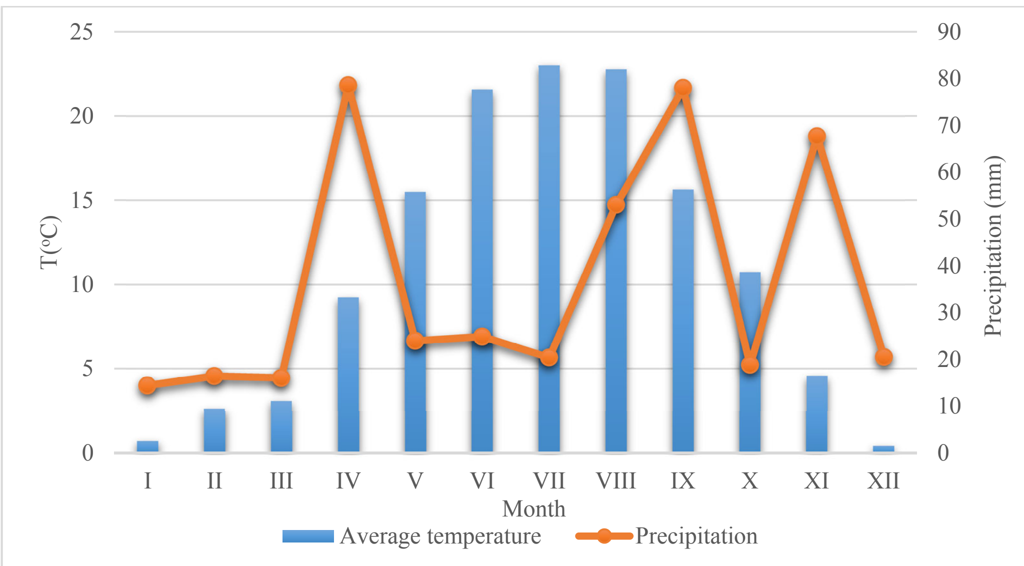


Figure 3 – Precipitation amounts and average monthly temperatures for 2022 year

To determine the bulk density, undisturbed soil samples were taken, 2-3 days after maize sowing and harvesting, using cylinders (5 cm diameter, 5.1 cm height) with a volume of 100 cm^3 and a bottom cut at an angle of 15°. In each plot, samples were taken from 3 points on the diagonal at 4 depth intervals: 0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm. The chosen samples were taken a long way from the areas' external edges in order to avoid border effects. The soil surface from which samples were taken was cleared of plant debris and gently levelled to ensure a sufficient surface area to sample 3 replicates at each depth.

Soil samples were then dried to a constant weight in a 105°C oven in the lab. The soil's weight was noted, and the bulk density was computed using *Equation 1* (Canarache, 1990):

Bulk density (g/cm^3) = (weight of oven dried soil) / (volume of the soil) (1)

The bulk density values are interpreted according to *Table 1*.

Table 1 – Characterisation of bulk density (according to ICPA Bucharest, 1987)

Characterisation	Values (clay-loam texture)
Extremely low	< 1.05
Very low	1.06-1.18
Low	1.19-1.31
Medium	1.32-1.45
High	1.46-1.58
Very high	>1.59

Note: ICPA – National Research and Development Institute for Soil Science and Agrochemistry in Bucharest - Romania

In order to determine the gravimetric soil moisture regime in the experimental field, soil samples were taken in six intervals up to 90 cm depths (0–10, 10–20, 20–30, 30–50, 50–70, and 70–90 cm) with three replicates at each interval. Soil (20–25 g) from five points were collected individually from each plot in aluminium vials. Moisture content was determined in the laboratory by the gravimetric method, which is considered the standard method for calibrating moisture metres due to its high accuracy.

The soil resistance to penetration was determined using the Eijkelkamp penetrologger in 10 replicates on each plot to a depth of 80 cm to obtain a representative value (expressed in MPa).

Some physical and hydro-physical properties (AP: aeration porosity; CD: compression degree) were calculated using specific formulas and field data.

The compression degree is an indicator that includes the bulk density, total porosity, and soil texture (*Equations 2* and *3*) (Canarache, 1990):

$$CD = \frac{PMN - TP}{PMN} \times 100 \quad (2)$$

$$PMN = 45 + 0.163 \times A \quad (3)$$

where: CD is the compression degree (% v/v), TP is total porosity (% v/v), PMN is the required porosity (% v/v), and A is the clay content below 0.002 mm (% g/g).

Characterisation of the compression degree is carried out according to *Table 2*.

The aeration porosity is calculated according to *Equation 4* (Canarache, 1990):

$$AP = TP - CC \times BD \quad (4)$$

where AP is the aeration porosity (% v/v), TP is total porosity (% g/g), CC is field capacity (% g/g), and BD is the bulk density (g/cm^3).

Taking into account the following expression, information regarding soil total porosity (TP) was obtained (*Equation 5*) (Canarache, 1990):

$$TP = (1 - \frac{BD}{D}) \times 100 \ (\% \ v/v) \quad (5)$$

where TP is total porosity (% v/v), BD is the bulk density (g/cm^3), and D is the soil density (assumed to be 2.68 g/cm^3).

Table 2 – Characterisation of the compression degree (according to ICPA Bucharest, 1987)

Characterisation	Values (% v/v)
Very loosened	<-17
Medium loosened	-17– -10
Weakly loosened	-9–1
Weakly compacted	1–10
Medium compacted	11–18
Very compacted	>18

Statistical analysis

The means and standard errors are used to express the data (SE). The effect of tillage systems on soil compaction was examined using one-way analysis of variance (ANOVA).

Using SPSS version 26, the significant differences between the treatments were determined using Tukey's post-hoc analysis with a 95% level of confidence.

RESULTS AND DISCUSSION

Influence of tillage systems on soil compaction

By reducing tillage and switching to conservation tillage, there is an increase in compaction and bulk density in the upper soil layers with low variation over time. The influence of soil tillage on bulk density (BD) and CD is of particular importance and can be observed in the case of the no-till system, where the values were not very different during the agricultural year.

During the growing season, BD increased in the conventional system at all depths, while the no-till system showed lower values between the two consecutive sampling times in the 0–30 cm layers (*Table 3*).

Blanco-Canqui and Ruis (2018) showed that BD increased with depth in soil profiles because the soil is gradually deposited under the influence of precipitation, particle resettlement, wetting, and drying.

Table 3 – Influence of tillage systems on soil compaction indices

Specification	Bulk density - BD (g/cm^3)				Compression degree - CD (% v/v)			
	Sowing		Harvesting		Sowing		Harvesting	
Tillage system	CT	NT	CT	NT	CT	NT	CT	NT
0-10 cm	1.05 ± 0.01 c	1.32 ± 0.04 b	1.16 ± 0.05 b	1.24 ± 0.02 b	-19.22 ± 0.01 c	-0.44 ± 2.80 b	-11.18 ± 1.44 b	-6.35 ± 1.54 b
10-20 cm	1.19 ± 0.05 bc	1.45 ± 0.01 a	1.41 ± 0.01 a	1.37 ± 0.03 a	-8.98 ± 3.35 bc	9.15 ± 0.96 a	7.11 ± 0.42 a	3.26 ± 1.57 a
20-30 cm	1.26 ± 0.04 b	1.44 ± 0.01 ab	1.39 ± 0.01 a	1.38 ± 0.03 a	-3.27 ± 3.17 ab	8.57 ± 0.81 ab	6.19 ± 0.42 a	4.15 ± 2.25 a
30-40 cm	1.42 ± 0.01 a	1.42 ± 0.04 ab	1.43 ± 0.01 a	1.43 ± 0.03 a	6.85 ± 0.30 a	5.56 ± 2.72 ab	7.57 ± 0.41 a	6.29 ± 1.92 a

Note: CT – conventional system; NT – No-tillage system. Mean ± standard error of each column is reported in correspondence with each experimental treatment. Within each column: values associated with the same lower-case letters are not statistically different at $p \leq 0.05$ according to Tukey's test.

Under the conventional tillage system, the BD is extremely low at the 0–10 cm interval, low at the 10–30 cm interval, and medium at the last sampling interval. At the end of the growing season, with the exception of the topsoil which has very low BD values, the other layers (10–40 cm) have medium BD. According to Afzalinia *et al.* (2014), soil bulk density had lower values at the end of the growing season compared to the sowing time, probably due to the higher development of maize roots at the end of the growing season.

In the case of the no-tillage system the BD indicates a weakly compacted soil, with a 14% positive difference between the average values on the 0-40 cm depth at sowing and only 1% at harvest compared to the conventional system. In the topsoil (0–10 cm) BD showed higher values for the entire agricultural year. These results are similar to those reached by Tian *et al.* (2022) that reported a higher value of BD in the topsoil of NT treatments in a 7 years experiment. In contrast to the classical system where BD increased during the growing season, the BD of the no-tillage system was lower at the 0-40 cm interval after harvest compared to the sowing time.

In the maize crop, the conventional tillage system showed the highest CD from sowing to harvest, where at the beginning it was very loosened (0-10 cm) and weakly loosened (10–30 cm) due to tillage, but at the end of the growing season, the values showed a weakly compacted soil (10–40 cm). Boja *et al.* (2010) concluded that the conventional tillage system has the superior values of CD.

In the no-tillage system, the CD at harvesting was close to that obtained at sowing, being weakly loosened in the soil surface layer and weakly compacted in the 10-40 cm range.

Influence of tillage systems on soil porosity

The values of total porosity (TP) have low variations over depth in the no-tillage system, with an increase during the growing season, leading to improved water holding capacity and better aeration in the soil. In the no-tillage (NT), the soil has a medium to high TP, both at sowing and at harvest time.

In the conventional system (CT) the values of TP decreased over time. The values of TP after harvesting show significant differences only in the topsoil (0-10 cm), being higher in the CT (60.82 % v/v) compared to the NT (50.75 % v/v) (*Table 4*). In a study conducted by Amin *et al.* (2014) it was reported that the no tillage system leads to a decrease of total soil porosity. In another study the total porosity was different among treatments only in the surface soil (0–10 cm), where the CT had the greatest volume of pores (Suzuki *et al.*, 2022).

Aeration porosity (AP) has higher values in the conventional system in both the spring and autumn periods. The highest values are recorded at the soil surface, and decrease with depth.

Influence of tillage systems on penetration resistance

Penetration resistance was performed up to a depth of 80 cm for both tillage systems, but the interpretation of the results were performed only in the 0-40 cm range in order to associate the results with the other parameters (*Figure 4)*.

The biggest difference is observed in the 0-30 cm soil surface layer, where the soil penetration resistance, in the conventional system, had lower values than the no-tillage system at the beginning of the growing season, due to the tillage for seedbed preparation. The higher values in vegetation due to the fact that the soil has settled, and there have been machine passes. In an experience with similar tillage systems, Martinez *et al*. (2008) reported significant differences in soil penetration resistance, only for the topsoil.

The maximum value of penetration resistance after sowing is 2.6 MPa in the conventional system and 1.87 MPa in the no-tillage system. These maximum values indicate a low penetration resistance, which is optimal for plant root growth.

During the growing season, penetration resistance values became higher in the conventional system throughout the analysed depth range (0-80 cm). The maximum value, of 4.3 MPa recorded at a depth of 40 cm, indicate a medium penetration resistance.

At harvest time, the soil penetration resistance of each system had similar values to that of the growing season, with the no-tillage system having lower values than the conventional, starting from low penetration resistance in the 0-40 cm range to medium resistance up to 80 cm.

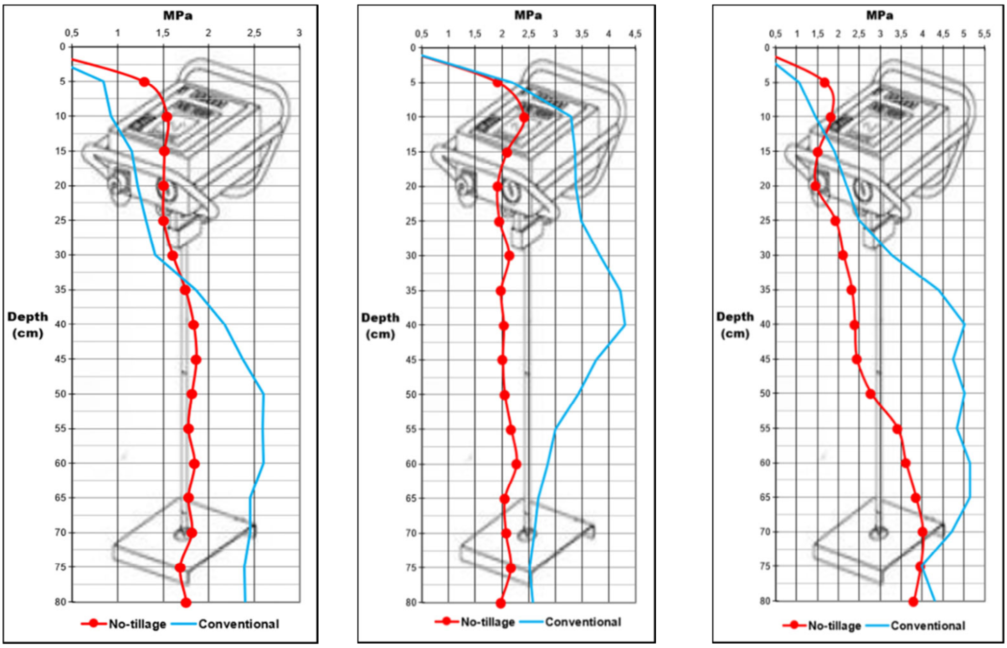
Influence of tillage systems on the soil moisture regime

When studying the mean values of available moisture in the maize crop, we found that it decreased during the growing season because of the lack of rainfall. Conventional tillage system by ploughing reorganizes soil particles physically, disrupts connective pores and modifies the pore size distribution, which leads to a direct change in soil water holding capacity (Zúñiga *et al.*, 2019).

Table 4 – Tillage techniques effects on soil porosity

Specification	Sowing				Harvesting			
Tillage system	NT		CT		NT		CT	
Soil porosity	TP (% v/v)	AP (% v/v)	TP (% v/v)	AP (% v/v)	TP (% v/v)	AP (% v/v)	TP (% v/v)	AP (% v/v)
0-10 cm	50.75 ± 1.41 a	9.05 ± 2.61 ns	60.82 ± 0.01 a	15.81 ± 0.19 ns	53.73 ± 0.78 a	11.8 ± 1.48 ns	56.71 ± 1.68 a	22.38 ± 2.20 a
10-20 cm	45.90 ± 0.48 b	5.93 ± 0.65 ns	55.60 ± 1.71 ab	12.05 ± 3.07 ns	48.88 ± 0.79 b	8.04 ± 1.34 ns	47.38 ± 0.24 b	13.08 ± 0.56 b
20-30 cm	46.27 ± 0.41 ab	5.48 ± 0.75 ns	52.99 ± 1.63 bc	10.37 ± 2.99 ns	48.51 ± 1.14 b	6.56 ± 2.08 ns	48.13 ± 0.22 b	9.63 ± 0.38 bc
30-40 cm	47.80 ± 1.38 ab	8.12 ± 2.08 ns	47.79 ± 0.15 c	8.19 ± 0.00 ns	47.43 ± 0.97 b	7.14 ± 1.72 ns	47.42 ± 0.21 b	5.28 ± 0.38 c

Note: CT – conventional system; NT – no-tillage system; TP – total porosity; AP – aeration porosity. Mean ± standard error of each column is reported in correspondence with each experimental treatment. Within each column: ns means—no statistically significant difference, and values associated with the same lower-case letters are not statistically different at $p \leq 0.05$ according to Tukey's test.



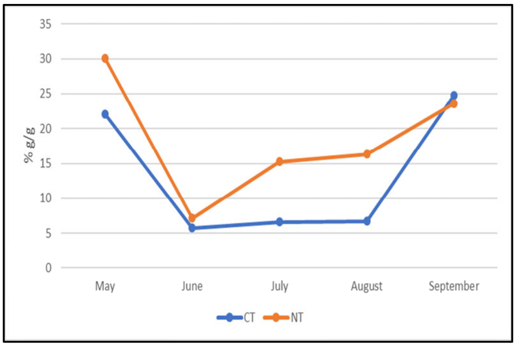
Sowing Vegetation Harvesting

Figure 4 - Evolution of soil penetration resistance during the growing season

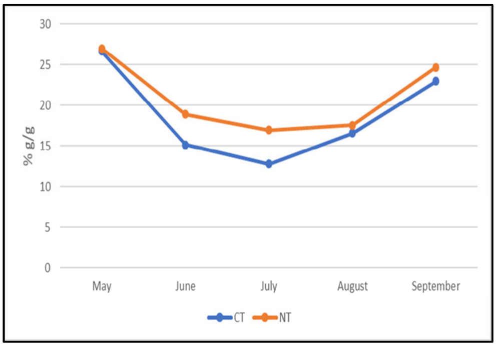
A difference in soil moisture at each sampling depth is evident between both systems, where the no-tillage system conserves more water especially during dry years. Over time, research showed that the cultivation system plays an important role in changing the moisture content of the soil (Yin *et al*., 2015). No-tillage systems conserves more soil moisture by increasing water infiltration and reducing evaporation (Moreira *et al*., 2016). The conservation tillage systems lead to the accumulation, conservation and gradual use of water in the soil by crop plants, water being an essential factor in vital processes in the plant (Chetan *et al*., 2011). These results are similar to those reached by Al-Wazzan *el al*. (2022) which found that applying a no-tillage system increases the amount of water available for plant growth and decreases water evaporation.

In September, after a considerable amount of rainfall, soil moisture in the no-tillage system hads relatively constant values in the range of 0-70 cm, due to a well-developed pore system and better infiltration rate resulting from the absence of ploughing. Similar results were obtained in a study by Budu *et al*. (2022) where the NT system had a higher moisture level compared to the conventional system on the 0 - 30 cm depth soil layer, in july (after 3 months from sowing) and after harvested. It was indicated by Slawinski *et al*. (2012), that the no-till system is essential for conserving soil moisture content.

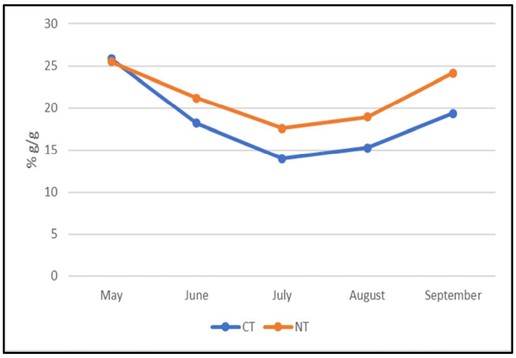
The effect of tillage systems on the soil moisture regime is summarised in *Table 5* and graphically represented in *Figure 5*.



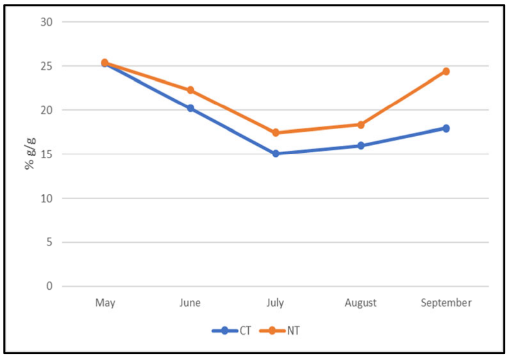
a. Depth 0-10 cm



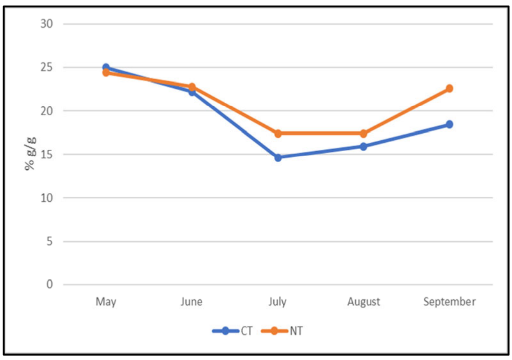
b. Depth 10-20 cm



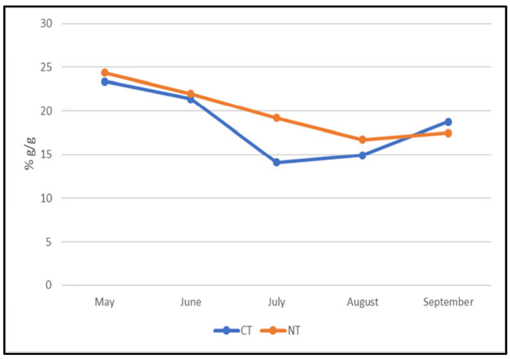
c. Depth 20-30 cm



d. Depth 30-50 cm



e. Depth 50-70 cm



f. Depth 70-90 cm

Figure 5 - Influence of tillage systems on the soil moisture regime

According to the results obtained, the no-tillage system has a higher moisture content than the conventional system, under the same climatic conditions, for all determinations.

The differences in average values for depth 0-90 cm are between 6% in May and up to 35% in July.

Table 5 - Influence of tillage systems on the soil moisture regime (% g/g)

	May		June		July		August		September	
	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT
0-10 cm	22.10 ± 1.54 b	30.10 ± 0.38 a	5.74 ± 0.56 d	7.14 ± 0.26 b	6.61 ± 2.36 b	15.22 ± 0.73 ns	6.73 ± 0.86 b	16.33 ± 1.65 ns	24.79 ± 1.24 ns	23.61 ± 1.48 a
10-20 cm	26.63 ± 0.30 a	26.95 ± 1.19 ab	15.13 ± 0.27 c	18.87 ± 2.00 a	12.77 ± 0.30 a	16.93 ± 0.09 ns	16.54 ± 1.78 a	17.53 ± 2.12 ns	22.96 ± 0.77 ns	24.64 ± 0.78 a
20-30 cm	25.86 ± 0.86 ab	25.47 ± 0.58 b	18.19 ± 0.75 b	21.18 ± 1.35 a	13.96 ± 0.72 a	17.59 ± 0.44 ns	15.28 ± 0.61 a	18.9 ± 1.50 ns	19.34 ± 1.34 ns	24.14 ± 0.62 a
30-50 cm	25.32 ± 0.34 ab	25.38 ± 0.49 b	20.21 ± 0.47 ab	22.29 ± 0.77 a	15.07 ± 0.13 a	17.44 ± 0.55 ns	15.99 ± 0.33 a	18.32 ± 0.97 ns	17.94 ± 2.05 ns	24.42 ± 0.12 a
50-70 cm	24.97 ± 0.34 ab	24.4 ± 0.8 b	22.24 ± 0.16 a	22.81 ± 0.29 a	14.64 ± 0.46 a	17.39 ± 1.23 ns	15.94 ± 0.16 a	17.42 ± 1.35 ns	18.41 ± 1.56 ns	22.6 ± 0.83 a
70-90 cm	23.39 ± 0.72 ab	24.36 ± 0.35 b	21.37 ± 0.21 a	21.96 ± 0.40 a	14.09 ± 0.56 a	19.2 ± 1.43 ns	14.91 ± 0.38 a	16.71 ± 1.43 ns	18.74 ± 1.68 ns	17.46 ± 1.51 b

Note: CT – conventional system; NT – No-tillage system. Mean ± standard error of each column is reported in correspondence with each experimental treatment. Within each column: ns—no statistically significant difference; values associated with the same lower-case letters are not statistically different at $p \leq 0.05$ according to Tukey's test.

CONCLUSIONS

The physical properties of soil measured in this study indicate that the physical quality was better under the NT than the CT. The tillage system can improve the soil's physical properties, especially by reducing the resistance of penetration and the variation of the BD and the soil CD and improving the moisture regime during the growing season. The BD increased under the conventional system both during the growing season and with depth, with the highest value at 30–40 cm. Mean of BD shows differences of 14% in NT compared to CT at sowing, a percentage difference that reaches only 1% at the end of the growing season, due to the increase in bulk density in the CT system and the fact that bulk density decreased from sowing to harvesting in the NT system, a phenomenon due to the root growth.

The degree of compression increased in the conventional tillage system from very loosened (-19.22% v/v) at sowing to weakly compacted (7.57% v/v) at harvest. In the no-tillage system, the values indicate a weakly compacted soil throughout the year, with the exception of the soil surface layer which was less affected by soil compaction (-6.34% v/v).

TP had low variations over depth in the no-tillage system, with an increase during the growing season, leading to better soil aeration. AP has higher values in the conventional system in both spring and autumn time. The highest values are recorded at the soil surface and decrease with depth.

For soil penetration resistance, at the beginning of the growing season, the values in the 0–40 cm range are lower in the conventional system than in the NT system as result of soil tillage for sowing. During the growing season, due to maize cultivation and the fact that soil has settled, the penetration resistance increased at all depths, reaching a value of 4.3 MPa at a depth of 40 cm, indicating a medium penetration resistance. The no-tillage system had relatively constant values during the growing season.

The difference in moisture content is evident between CT and NT systems. The no-tillage system retains more water than the conventional system, which had moisture values close to the wilting point in July. After a dry year and the first heavy rains, an increase in moisture was observed in the 0–70 cm interval in the no-tillage system (in September), compared to the conventional system, where moisture increase occurred only in the surface layers. This is mostly due to the more developed capillary system and the higher water infiltration rate into the soil.

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