NO-TILLAGE IMPACT ON HYDRO-PHYSICAL PROPERTIES OF THE SOIL ON CORN CROP

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Abstract

Water content is essential for all soil processes. It functions as a transfer medium for nutrients in the soil solution, as well as a source of water needed for plant growth and development. The practice of no-tillage, compared to conventional tillage, has a positive influence on the continuity of the soil pore system, with direct effects on water and air circulation. The present scientific research investigates the dynamics of hydro-physical properties in tillage systems practiced in the experimental field of the Soil Management Department in Ezăreni Farm, Iasi University for Life Sciences, Romania. It is geomorphologically located on the transition Coast of Iasi, in a plateau area, with a cambic chernozem soil, with clay-loam texture. Soil samples were collected from the reference plots in undisturbed natural settlement, using 100 cm^3 metal cylinders to determine the hydraulic conductivity. Soil samples were also taken at a depth of 0-90 cm for gravimetric moisture determination and WatchDog sensors (SM100) were placed at a depth of 10-30 cm at the beginning of the growing season for volumetric moisture measurement. In the field, the infiltration rate of water into the soil was determined using the double ring infiltrometer. The results confirm that the no-tillage system conserves more water in the soil, has higher saturated hydraulic conductivity values, from 0.196 at 30-40 cm depth to 1.209 (cm/s x 10^{-2}) at 20-30 cm depth, and the infiltration rate determined in the field is 4% higher compared to the conventional system.

Key words: soil moisture, infiltration rate, saturated hydraulic conductivity

Conservation tillage is associated with noninversion of soil, resulting in the maintenance of at least 30% of the soil surface coverage with crop residues after seeding. In particular, conservation tillage measures vary with depth and width of cultivation, and are classified as no-till, ridge-till, strip-till, mulch-till, and reduced-till techniques. In Europe, conservation tillage is practiced on 26% of the total arable land (Madarasz B. *et al*, 2021), in Germany, 34% of all farms are managed under reduced tillage, and only 1% of the arable land is cultivated in no-tillage systems (Zikeli S. *et al*, 2017).

Conservation tillage is well-recognized as a potential strategy to increase the agricultural sustainability by preserving soil and water resources and improving the production economy, among other agroecosystem services (Van den Putte A. *et al*, 2010).

Due to accumulating plant residues on soil surfaces, no-tillage generally has a more intense and immediate effect on topsoil than on subsoil properties. For instance, no-tillage has generally resulted in a greater wet aggregate stability (Bottinelli N. *et al*, 2017), macro-aggregation (Kibet L.C. *et al*, 2016), and water content (Parkin G. *et al*, 2013) at surface soil layer compared with conventional tillage.

Some studies have reported inconsistent results when soil hydro-physical properties were compared between no-tillage and reduced tillage systems. For example, compared with reduced tillage, no-tillage resulted in higher (Acar M. *et al*, 2018; Al-Kaisi M. *et al*, 2014), lower (Alam M. *et al*, 2017; Villamil M.B. *et al*, 2015), or similar (Bottinelli N. *et al*, 2017) aggregate stability and size distribution. Contradictory results can also be found in soil hydraulic properties and crop yield when comparing between reduced and no-tillage systems (Alam M. K. *et al*, 2017).

Conservation tillage, which includes a variety of reduced and zero tillage techniques that leave at least 30% crop residue on the soil surface, has increasingly been adopted as the agricultural best management practice to reduce soil erosion. These tillage practices significantly affect surface hydrologic properties, leading to increased infiltration and reduced runoff (Singh A. *et al*, 2009; Van Wie J.B. *et al*, 2013).

Variable soil bulk density due to human disturbances and environmental effects is an important factor causing temporal and spatial

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variations in soil hydraulic properties (Zhang M. *et al*, 2017; Tian Z. *et al*, 2018a). After tillage, soil bulk density tends to increase with time under the influences of gravity, rainfall and water flow into the soil (Tian Z. *et al*, 2018b), which results in a substantial decrease in the saturated soil hydraulic conductivity. The unsaturated soil hydraulic conductivity response to bulk density variation induced by traffic compaction or tillage was shown to exhibit complex behaviors in space and time (Strudley M.W. *et al*, 2008).

Several studies have evaluated the effects of conservation agriculture on the physical parameters of soil (Bhattacharya P. *et al*, 2020; Ajayi A.E. *et al*, 2021). The main improvements reported are in terms of aggregate stability, infiltration rate (Blanco-Canqui H. *et al*, 2018), and air permeability (Vogeler I. *et al*, 2009).

Saturated hydraulic conductivity (Ks) is an important soil property that determines the ability of soil to transmit water under saturated conditions, is potentially affected by management practices such as tillage that impact physical properties, and plays an integral role in many soil, environmental, and hydrological processes. Previous studies showed that Ks can vary considerably over space and time within agricultural fields, indicating spatial and temporal variability (Kargas G. *et al*, 2021).

Blanco-Canqui H. (2018) evaluated the effect of no-tillage, chisel plow, disk and moldboard plow tillage practices on total porosity, water infiltration, saturated hydraulic conductivity, and water retention characteristics under continuous corn after 35 years in silty clay loam soils in eastern Nebraska. They reported no significant differences in any of these soil hydraulic properties among the four tillage systems. Meanwhile, numerous studies suggested that tillage increases saturated hydraulic conductivity as a result of increasing soil macroporosity and disturbance induced by mechanical effects of tillage processes (Schluter S. *et al*, 2020; Haruna S.I. *et al*, 2018).

Haruna (2018) studied the influence of tillage and cover crops on soil hydraulic properties including saturated hydraulic conductivity. They concluded that tillage increased the proportion of coarse soil mesoporosity by 32%, resulting in 87% greater saturated hydraulic conductivity compared to under no-tillage practices.

There is not a singular conservation tillage system that can satisfy all agroecosystem services for soil quality, environmental sustainability, and economic outcome across soils, climates, and crops. Hence, there is a need for region-specific designs of tillage and cropping systems to obtain the maximum outcome within certain climatic and terrestrial boundaries. Our research is based on a field experiment established in 2014 on a cambic chernozemic soil with a rotation of winter wheat, maize, sunflower and pea, where maize crop was studied. Our research objective was to determine some hydrophysical parameters such as bulk density, total porosity, hydraulic conductivity, infiltration rate, gravimetric moisture, volumetric moisture and electrical conductivity.

MATERIAL AND METHOD

In this study, the dynamics of hydro-physical properties during the agricultural year 2022-2023 in corn crop are investigated. The experimental field (*figure 1*) where the study was conducted belongs to the Soil Management Department, being located in Ezăreni farm, Iasi University for Life Sciences, Romania. 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 (SRTS 2012, a clay-loam texture and 6.8 pH units.

The total area is 16 ha, of which 8 ha are cultivated in conventional system (CT) and 8 ha in no-tillage (NT), using the Fabimag FG – 01 seed drill (*figure 2*). The maize crop area is 4 ha, divided into two plots, one for each tillage system.

Figure 1 **The experimental field**

Figure 2 **Seed drill Fabimag FG-01**

The experimental field has been cultivated in the no-tillage system since 2014, with a 4-year rotation of winter wheat, maize, sunflower and peas.

The experimental site has a annual average temperature 10.8˚C and precipitation of 691 mm and 432.8 mm in 2021 and 2022, respectively. In 2023, until the second decade of September, 336.4 mm of precipitation was recorded, with a maximum of 136 mm in July and a minimum of 5.6 mm in March. In terms of temperature variation in 2023, they ranged from -16.4 ºC (9 February) to 38.8 ºC (28 August), data recorded by Ezăreni weather station (*figure 3*).

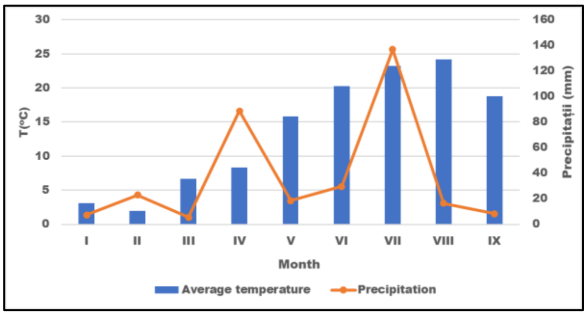


Figure 3 **Precipitation amounts and average monthly temperatures for January-September 2023**

For the measurements of bulk density (BD) and saturated hydraulic conductivity (Ks), undisturbed soil samples were taken, after sowing and during the growing season using stainless-steel cylinders with a height of 5.1 cm and diameter of 5.0 cm (volume: approximately 100 cm^3) on 4 depths between 0 and 40 cm.

For BD determination soil samples were transferred to the laboratory, placed in an oven at 105 °C and dried to a constant weight. The weight of the soil was recorded and the BD was calculated using Eq. 1(Canarache A., 1990):

$$\text{Bulk density (g/cm}^3) = \frac{\text{weight of oven dried soil}}{\text{volume of the soil}} \quad \text{(Eq. 1)}$$

Ks was measured using a falling-head permeameter (Hauben water permeameter, Eijkelkamp Agrisearch Equipment) under conditions of instationary flow. For the Ks measurements, the samples were pre-saturated for two days in a container and then flooded for the measurement. The Ks was calculated by Equation (2) (Lal R. *et al*, 2004, Eijkelcamp, 2017).

$$k = \frac{a * l}{A * t} * \ln \frac{h1}{h2} \quad \text{(Eq. 2)}$$

where a is the burette area (cm^2), l is the height of the stainless-steel cylinders (cm), A is the area of the stainless-steel cylinders (cm^2), t is the time interval (s), and h1 and h2 are the water level at the start and end points of the measurements (cm).

The double ring infiltrometer (DRI) method was used to measure the infiltration rate of water in soil. The DRI consists of two open stainless-steel rings, of which one is placed inside the other. The inner and outer rings are 300 mm and 550 mm in diameter, respectively. By partially driving these into the soil and filling the rings with water, an above-ground reservoir is thus formed that is directly located above the set of soil that is being tested. The outer ring limits the lateral spread of water after infiltration so that one-dimensional, vertical flow is promoted beneath the inner ring (ASTM, 2009).

Infiltration rate measurements were carried out in July, in the second decade, on two consecutive days, in order to have similar soil moisture conditions in both systems. The infiltration rate was calculated by Equation (3) and (4):

$$v(t) = \frac{1}{2} * S * t^{-\frac{1}{2}} + A \quad \text{(Eq. 3)}$$

$$K = \frac{A}{m} \quad \text{(Eq. 4)}$$

where v(t) is infiltration rate, s is sorptivity, t is time, K is field saturated hydraulic conductivity, A is a parameter and m is a constant equal to 0,66667.

To determine the gravimetric soil moisture content 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.

Spectrum Technologies Water Scout SM100 soil moisture sensors (Spectrum Technologies, Aurora, IL) were installed on 31 May 2023 at 10, 20 and 30 cm soil depths to monitor soil moisture. At a depth of 30 cm, SM300 sensors were installed to monitor soil moisture, temperature and electrical conductivity. Soil moisture content was recorded as a percent volumetric water content at 60 min intervals continuously throughout the study period by Watch Dog 1000 micro weather field station (*figure 4*). Data were downloaded monthly to a laptop computer using Spectrum technologies SpecWare 9 pro software. The mean for every day was calculated from 60 min interval data and graphed for the whole study period. The manufacturer specifications provided by Spectrum technologies for Waterscout SM100 sensor indicated that the sensor resolution for volumetric moisture measurement is 0.1% with an accuracy of ±3% at EC <8 mS/cm and 0.5 - 80 ◦C temperature range (Spectrum Technologies, 2019).

Figure 4 **Watch Dog 1000 Micro Weather Field Station with moisture senzor**

The data results are expressed as the means ± standard error (SE). One-way analysis of variance (ANOVA) was used to see the influence of tillage systems on soil compaction. The significant differences between treatments were established using Tukey's post-hoc test with a degree of confidence of 95% using SPSS ver. 26.

RESULTS AND DISCUSSIONS

Bulk density (BD) and total porosity (TP)

The influence of soil tillage system on BD is observed by a lower variation over time due to the non-working and less passes with agricultural machinery that cause soil compaction.

The BD has significantly different values between 1.21 and 1.42 g/cm^3 in the conventional system, with a maximum at a depth of 30-40 cm, which remains high during the growing season (*table 1*). In the NT system, the lowest values are recorded at the soil surface, in the 0-10 cm layer, of 1.24 at sowing and 1.26 g/cm^3 in vegetation, with a maximum registered at sowing of 1.45 g/cm^3 in the 10-20 cm soil layer, a density that decreases slightly during the vegetation period. With the exception of samples taken after sowing, the NT has a lower BD value in the topsoil layer. These results are in accordance with results of Gao *et al*, (2019) that reported significant higher BD value, in the 0–10 cm layer in CT than that of NT. A recent review paper synthesizing results from 62 studies indicated that NT can either increase or decrease soil BD, depending on the longevity of tillage management (Blanco-Canqui H. *et al*, 2018). In both tillage systems the BD is low (1.19-1.31 g/cm^3) to medium (1.32-1.45 g/cm^3) (I.C.P.A., 1987).

The magnitude of differences in BD among tillage systems can also be affected by the time of sampling. BD is generally the lowest immediately after tillage operation and gradually increases during the growing season, due to climatic factors and the mechanical load exerted on the soil surface (Leik F. J. *et al*, 2002).

TP has significantly different values by depth at the beginning of the growing season under both systems, with a maximum value in the 0-10 cm soil layer of 54.68 % v/v in CT and 53.41 % v/v in NT and a minimum value of 47.39 % v/v in the 30-40 cm soil layer in CT and 45.73 % v/v in the 10-20 cm soil layer in NT.

During the growing season, TP values decrease in all depths studied, with the exception of the 10-20 cm soil layer, where porosity is improving in NT, and on the 20-30 cm layer in CT. A study conducted by Shittu K. A. (2017) reported that soil porosity is not influenced by tillage practices significantly. This result disagreed with the study of Amin M (2014), reported that NT system reduced of TP.

Tabel 1

Bulk density (BD) and total porosity (TP) as affected by tillage systems at depths between 0 and 40 cm

	BD (g/cm^3)		TP (% v/v)	
	Sowing	Vegetation	Sowing	Vegetation
Tillage treatments	0 – 10 cm			
CT	1.21 ± 0.04 a	1.33 ± 0.15 ns	54.68 ± 1.39 b	50.26 ± 5.42 ns
NT	1.24 ± 0.03 a	1.26 ± 0.02 a	53.41 ± 1.20 b	53.07 ± 0.67 b
	10 – 20 cm			
CT	1.29 ± 0.03 ab	1.38 ± 0.05 ns	51.51 ± 0.95 ab	48.51 ± 1.82 ns
NT	1.45 ± 0.02 b	1.41 ± 0.03 b	45.73 ± 0.85 a	47.29 ± 1.12 a
	20 – 30 cm			
CT	1.36 ± 0.03 b	1.27 ± 0.03 ns	49.02 ± 1.21 a	52.70 ± 1.15 ns
NT	1.37 ± 0.02 b	1.38 ± 0.02 b	48.63 ± 0.90 a	48.22 ± 0.81 a
	20 – 30 cm			
CT	1.40 ± 0.03 b	1.42 ± 0.03 ns	47.39 ± 1.01 a	47.12 ± 1.04 ns
NT	1.38 ± 0.03 b	1.42 ± 0.02 b	48.24 ± 1.02 a	46.98 ± 0.65 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.

Saturated hydraulic conductivity (Ks)

The Ks values after sowing are higher in the 0-10 and 10-20 cm depths due to seedbed preparation. Later, during the growing season, the Ks decreases in the CT system at depths 0-10 and 10-20 cm, but increases at depths 20-30 and 30-40 cm (*table 2*). In the NT the Ks improved during the growing season, with higher values compared to the CT. Similar results were obtained by Lavinia Burtan (2020), who performed a determination in September obtaining a higher conductivity in the NT (2.4 x 10^{-2} cm/s) compared to the CT system (1.9 x 10^{-2} cm/s). Contradictory results have been found regarding the soil tillage effects on Ks. In some situations, higher conductivity values have been observed in NT than CT (Alvarez R. *et al*, 2009; Singh P. *et al*, 2014), whereas the opposite have been reported in others (Soracco C.G. *et al*, 2012). De Moraes (2016) showed greater Ks for NT than CT at 10 cm depth.

Table 2

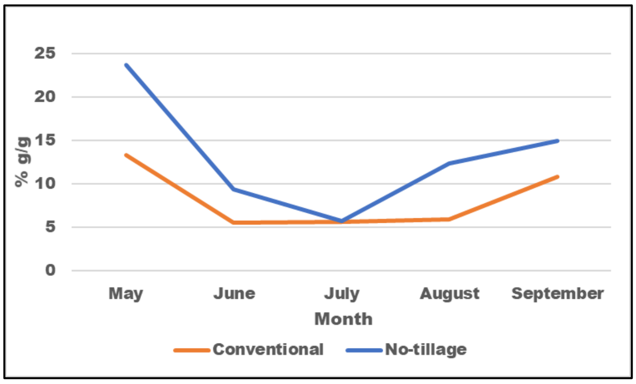
Effects of soil tillage on Saturated hydraulic conductivity (Ks)

Specification	**Sowing**		**Vegetation**	
	(x 10^{-2} cm/s)			
Tillage system	CT	NT	CT	NT
0-10 cm	2,386 ± 0.09 c	1,992 ± 0.06 b	2,081 ± 0.05 b	2,524 ± 0.04 a
10-20 cm	2,079 ± 0.05 b	1,653 ± 0.01 a	1,906 ± 0.03 a	2,569 ± 0.03 a
20-30 cm	1,807 ± 0.08 a	2,510 ± 0.12 c	2,022 ± 0.03 b	3,244 ± 0.06 b
30-40 cm	1,914 ± 0.05 ab	2.055 ± 0.04 b	2,357 ± 0.07 c	2,629 ± 0.05 a

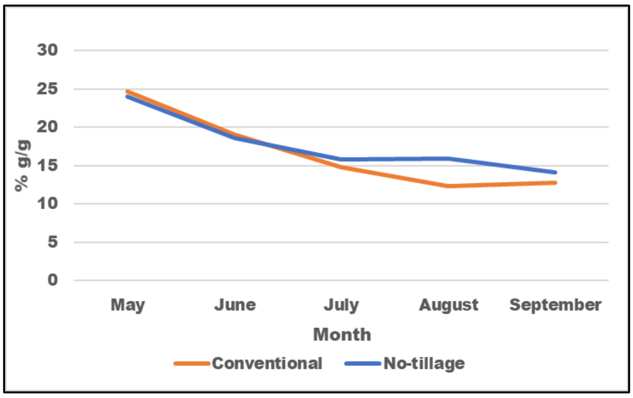
Note: CT – conventional system; NT – No-tillage system. Mean ± standard error of each column is reported in correspondence with each experimental treatment. Within each column: values associated with the same lower-case letters are not statistically different at $p \leq 0.05$ according to Tukey's test.

Gravimetric soil water content

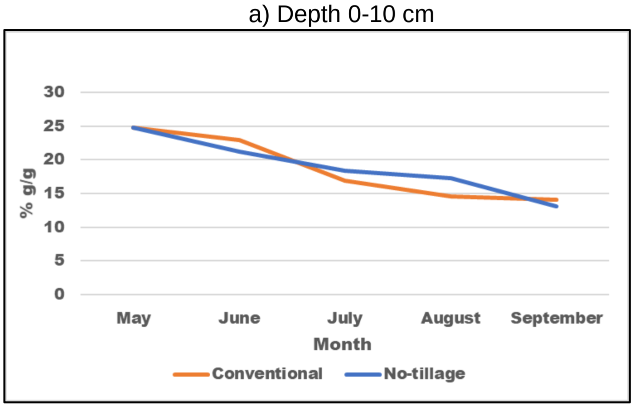
Moisture content was affected by tillage systems, especially in the upper soil layer (*figure 5a*). At 0-10 cm depth (*figure 5b*), the NT system has a higher water content throughout the growing season with differences ranging from 2% in July to 78% in May. NT reduces water evaporation and increases water availability for plant growth (Wazzan F. *et al*, 2022).



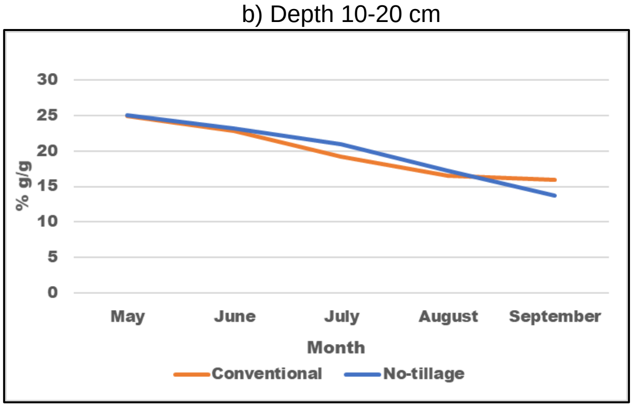
a) Depth 0-10 cm



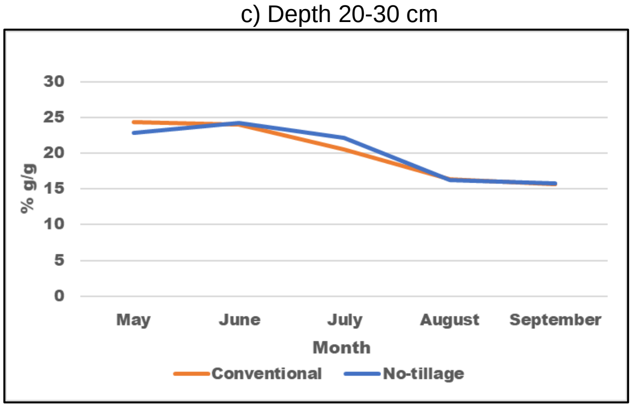
b) Depth 10-20 cm



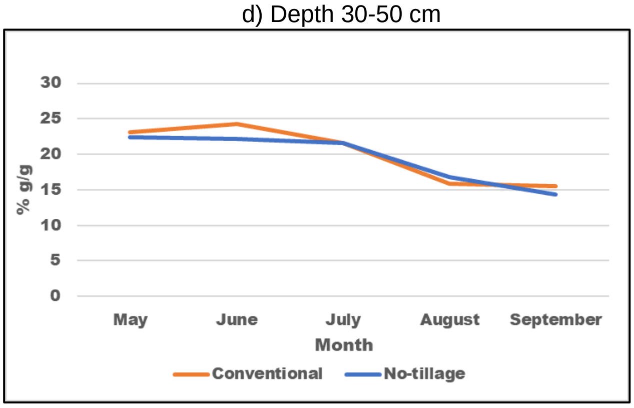
c) Depth 20-30 cm



d) Depth 30-50 cm



e) Depth 50-70 cm



f) Depth 70-90 cm

Figure 5 **Influence of tillage systems on gravimetric soil moisture**

Infiltration rate

The soil infiltration rates of different treatments decreased with increased infiltration time, and the changes of infiltration rates with time for all treatments were best displayed as a graphic. The average soil permeability values were 5.35 in NT and 5.14 cm/hour in CT, which shows that soil permeability was faster in the conservative system (*figure 6)*. Permeability value shows the ability of soil to pass water either laterally or horizontally. Permeability is influenced by the porosity and bulk density of the soil and closely related to soil texture (Arora V.K. *et al*, 2011).

Blanco-Canqui, H. (2018) compared 24 studies on water infiltration, and in only 15 studies the NT had a higher water infiltration compared to the CT. However, a few studies have indicated that NT may decrease or have no effect on water infiltration, suggesting that NT does not always increase water infiltration. Reduced till often has intermediate values of water infiltration between NT and CT.

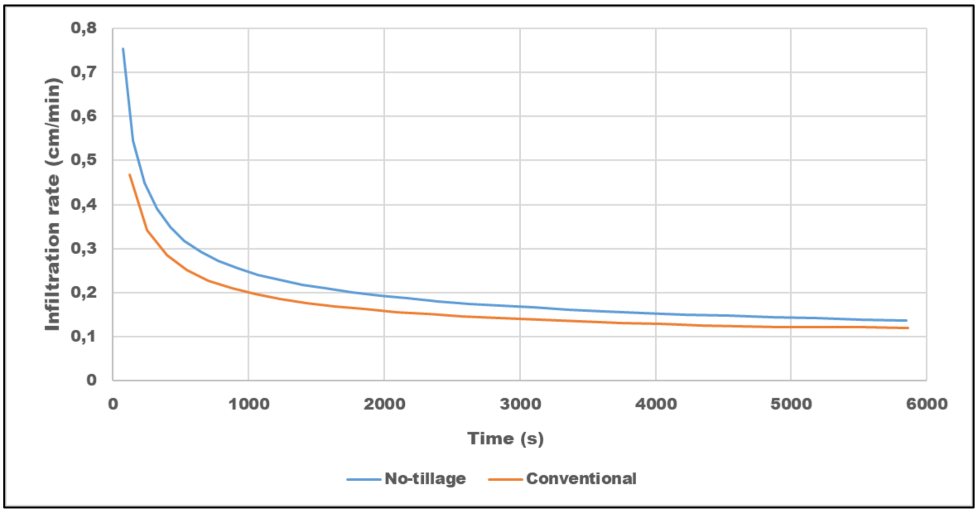


Figure 6 **Infiltration rate**

For the depth of 10-20 cm in May and June the soil moisture is slightly higher in the CT, and for the rest of the growing season the NT has a significant higher moisture content compared to the CT. The NT has a higher moisture value in July and August for the soil layer between 20 and 90 cm, and for the rest of the season the moisture is basically the same or slightly lower.

It has reported by Romaneckas K. (2009) and Slawinski C. (2012) that NT is important for saving the moisture content of the soil. The reason is that in the NT the crop residue is maintained on the ground surface that reduces water evaporation and more infiltration rate (Shittu K.A. *et al*, 2017). In the case of CT, the soil moisture content will be fluctuated after the periods of rainfall.

Volumetric soil water content

The soil moisture dynamics of the study field were determined at four soil depths from 31 May to 28 September 2023 (*figure 7)*.

According to the results obtained, the NT had a higher moisture content throughout the growing season for every depth studied. The exception was the 20 cm soil layer where the CT had a slightly higher moisture content in June.

Volumetric moisture values varied at each depth as follows, at 10 cm depth the CT system recorded a minimum of 15.54 % v/v on 14 June and a maximum of 40.36 % v/v on 8 July, and the NT system had a minimum moisture on 28 September of 24.7 % v/v, while the maximum on 8 July was 49.18 % v/v. At a depth of 20 cm the CT system recorded values between 28.9 (28 August) and 46.3 % v/v (8 July), compared to 36.2 (4 July) and a maximum of 49.5 % v/v (8 July). Finally, on the last depth studied, moisture values ranged from 24.45 (24 September) to 39.59 % v/v (8 July) in the CT system and from 27.8 (4 July) to 51.65 % v/v (8 July) in the NT system.

The most significant increase in moisture was recorded in the first decade of July, when the weather station on the farm recorded 97.4 mm.

During the growing season, following the significant amounts of precipitation, the moisture in the soil surface in the CT exceeded for a short time the NT.

Similar results were reported by Agbede T.M. (2010), who found significantly higher SWC under NT compared to CT. The same results were obtained by Semenikhina Julia (2020) in a study performed for a period of 2 years, where a higher moisture content was obtained in the NT using SM100 sensors.

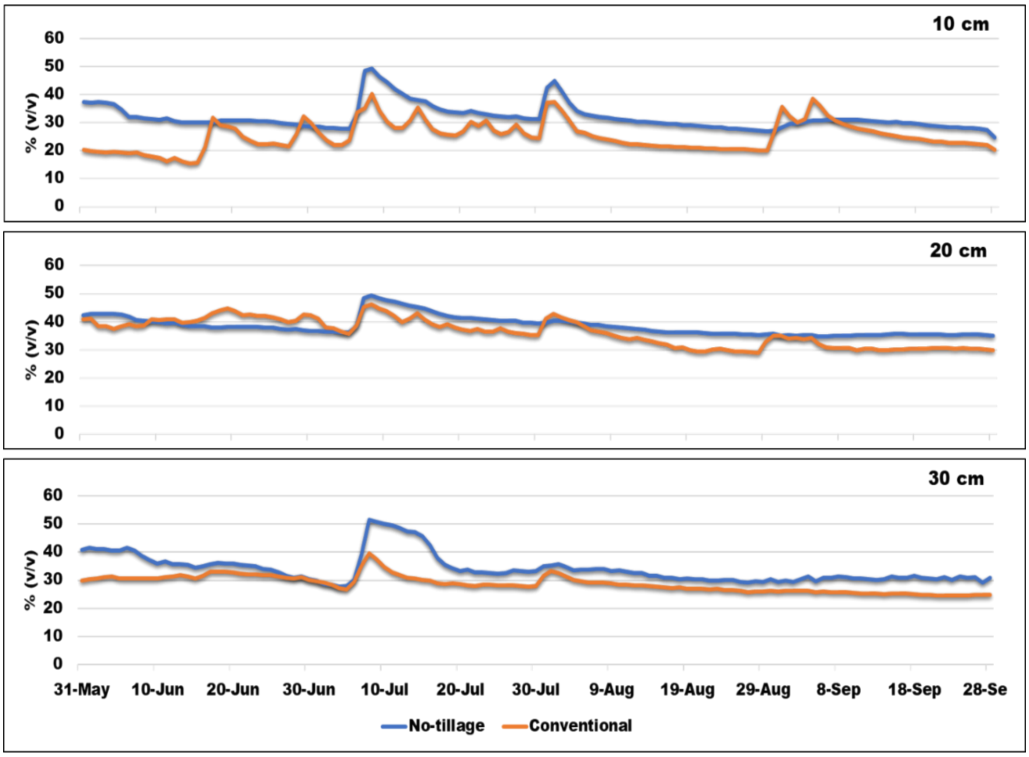


Figure 7 **Influence of tillage systems on the volumetric soil moisture**

Soil electrical conductivity (Ec)

Ec was measured using SM300 type sensors installed in both tillage systems at a depth of 30 cm. The results (*figure 8*) indicate a significantly better EC in the NT throughout the growing season, with a minimum of 0.38 mS/cm on 5 September and a maximum of 0.79 mS/cm on 7 July, except for the period from the beginning of the growing season between 1 and 10 June, when the CT recorded a higher Ec.

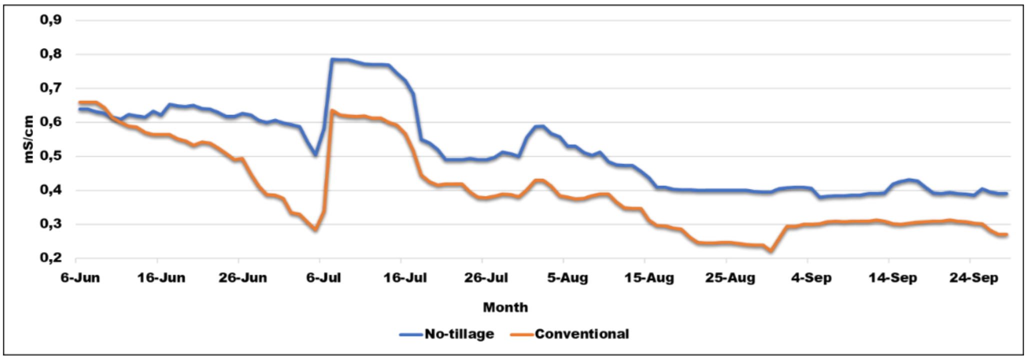


Figure 8 **Influence of tillage systems on the soil electrical conductivity**

CONCLUSIONS

The NT has a substantially impacts on soil hydro-physical parameters. The implementation of the NT on cambic chernozem soil in the climatic conditions of the Ezăreni farm, in an agricultural year affected by the current climatic problems, the most serious being drought, has better results compared to the CT. Increased BD values, higher Ks in vegetation period by 8% in 30-40 cm to 58% in 20-30 cm soil layer, higher soil moisture content, 4% better water infiltration rate and improved Ec throughout the growing season were reported.

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