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SOIL PHYSICAL PROPERTIES, SPECTRAL RESPONSE AND YIELD OF THE SUNFLOWER UNDER DIFFERENT TILLAGE SYSTEMS AT EZARENI FARM, IASI COUNTY, ROMANIA

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Abstract

The study analyzes the short-term effect of tillage systems on soil physical properties, spectral response and sunflower yield, was based on three tillage system NT (No-tillage); MT (Minimum tillage); and CT (Conventional tillage). Data collected include soil physical properties (PR: Penetration resistance, VWC-Soil water content, Ks-Soil hydraulic conductivity), crop's spectral response through different multispectral sensors, and yield. Results showed that the for Ks, the highest value was obtained with NT at depth 0-10 cm. Concerning PR, high values were respectively recorded with CT (3.54 Mpa) during the vegetative period of the plant and with MT (2.54 MPa) during the harvesting period. Grain yields were also influenced by the tillage systems and reached values of 2.105, 2.631 and 3.052 kg/ha, respectively for the NT, MT and CT systems. Yield was also affected by heavy draught.

Key words: *tillage systems, soil physical properties, spectral response, yield, sunflower.*

INTRODUCTION

Soil is an essential resource for biodiversity, soil fertility, and food security on a global scale. Its maintenance and sustainable management are therefore crucial in the face of the challenges posed by population growth and environmental change. Among the most effective strategies for preserving soil health are crop rotation, reduced chemical use, and tillage systems. These practices not only prevent phenomen such as erosion and biodiversity loss but also restore the ecological and agricultural functions of soils, ensuring their ability to support future food and environmental needs.

Tillage represents a fundamental agronomic practice that has been integral to the majority of agricultural systems for centuries (Busari et al., 2015). Seedbed development, soil aeration, reducing soil evaporation, increasing plant water availability, breaking soil crusts, controlling pests, and incorporating residues are some of its aims (Amézketa, 1999; Köller, 2003). Additionally, tillage practices seek to decrease nutrient loss while enhancing plant root penetration and soil nutrient redistribution for effective nutrient absorption (Wang et al., 2015). Conventional tillage (CT) was an important factor in the development of modern agriculture practices since it helped to increase crop yields and manage weeds (Ashapure et al., 2019). In essence, plowing completely inverts the soil, which is what defines the CT. On the other hand, no-tillage (NT) and non-inversion tillage methods are part of conservation systems (minimal tillage, MT). With these approaches, crops are planted with reduced to no soil disturbance and maintaining a minimum of 30% mulch cover to protect the soil surface (Giller et al., 2015).

Similar to many regions in Europe, the adoption of conservation tillage in Romania remains restricted, however interest is gradually increasing (Țopa et al., 2021). Research on agricultural tillage systems in Romania and worldwide has focused on enhancing soil structure, reducing soil compaction, improving hydrological and aeration conditions, increasing organic matter content, optimizing the activity of microorganisms, understanding the effects of chemical substances, and identifying critical pollution thresholds (Raus et al., 2016)

Compared to conventional tillage (CT), minimum tillage (MT) and no-tillage (NT) systems have become widespread adoption due to their potential to reduce fossil fuel consumption, enhance soil carbon sequestration, improve soil structure, and improve water infiltration. All of which contribute to maximize farm sustainability and production (Deubel et al., 2011; Ciri´c et al., 2012; Villamil and Nafziger, 2015; Zhao et al., 2017). The lack of soil plowing may worsen topsoil compaction, particularly in clayey soils and/or soils with low organic matter concentration (Secco et al., 2009; Franchini et al., 2012). Conversely, CT systems are recognized to typically diminish soil bulk density (BD) in the tilled layer (Dam et al., 2005; Wang et al., 2015) while enhancing soil porosity, hydraulic conductivity, and infiltration rate in the short term (Lampurlane and Cantero-Martínez, 2006; Schwen et al., 2011; Maharjan et al., 2018). Moreover, quantitative evaluations of crops under conventional tillage (CT), minimum tillage (MT), and no-till (NT) sometimes indicated contradictory, yielding varying responses conditional with the crop species (Salem et al., 2015; Pittelkow et al., 2015).

Plants potential to establish wide root systems is related to their capacity to gain nutrients and water from the soil (Chen and Weil, 2011; Dias et al., 2015). Tillage practices have the potential to promote soil compaction because they progressively change the physical characteristics of the soil. This result could limit plant access to subsurface water and root development during the growing season. This impact may, therefore, restrict plant development and alter its spectral response (Martins R.N. et al., 2021). Vegetation indices (VI) may be used to monitor the spectral characteristics of crops. The most widely and reliable VI is the normalized difference vegetation index (NDVI), which is derived from the reflectance of red and near-infrared (NIR) wavelengths (Rouse et al., 1973).

According to the research, there is a strong correlation between the NDVI and various biophysical factors, including agricultural production and biomass (Kross et al., 2015; Geipel et al., 2016; Zhou et al., 2017; Martins R.N. et al., 2021). In addition, over the years and with so many research studies carried out with a view to obtaining NDVI, a range of methods, remote sensing techniques and different sensors have been used. As an example, the space platforms used by Sakamoto et al. 2013, the aerial platform method used by Neiffield et al., 2015; Gabriel et al., 2017, uncrewed aerial vehicles (UAV) and proximal sensors (Stamatiadis et al., 2010; Hassan et al., 2019) were used to obtain NDVI.

With the emergence of drones, their use has become more frequent, given their flexibility, ease of handling, high spatial resolution, and ability to collect data on demand. As a result, drone systems enable accurate, high-resolution analysis and monitoring of crop time series quickly, non-deformably, and without extensive fieldwork (Yeom et al., 2019). Since tillage systems have a direct influence on the physical, chemical, and biological properties of the soil, this might also influence plant growth and development, and consequently their spectral response. However, the spatial resolution of UAV imagery is much finer and more exact than that of traditional remote sensing platforms, making it possible to observe variations in the growth-development process of plants and in their spectral response (Martins et al., 2021). The general objective of this study was the assessment of the short-term influence of three tillage systems on soil physical properties, spectral response, and sunflower crop yield.

MATERIALS AND METHODS

Study area

The study was conducted at the Ezăreni Research and Student Practice Station in Iasi, Romania (47˚12′ N latitude, 27˚51′ E longitude). The research was carried out on a soil type, characterized as Chernozem (WRB Classification) and clay-loam in texture with 36.1% clay, 26% silt and 37.9% sand. Its humus content varies between 2.7 and 3.4% and has a slightly acidic pH, according to the Romanian Soil Taxonomy System (SRTS 2012). The experimental research was carried out from April 2024 to October 2024 on the sunflower crop (*Helianthus annuus* L.) (Figure 1). This field area has an annual mean temperature 12.40°C and precipitation of 53.2 mm in 2024. (Figure 2), presents a 5% inclination and is located 126 m from sea level.

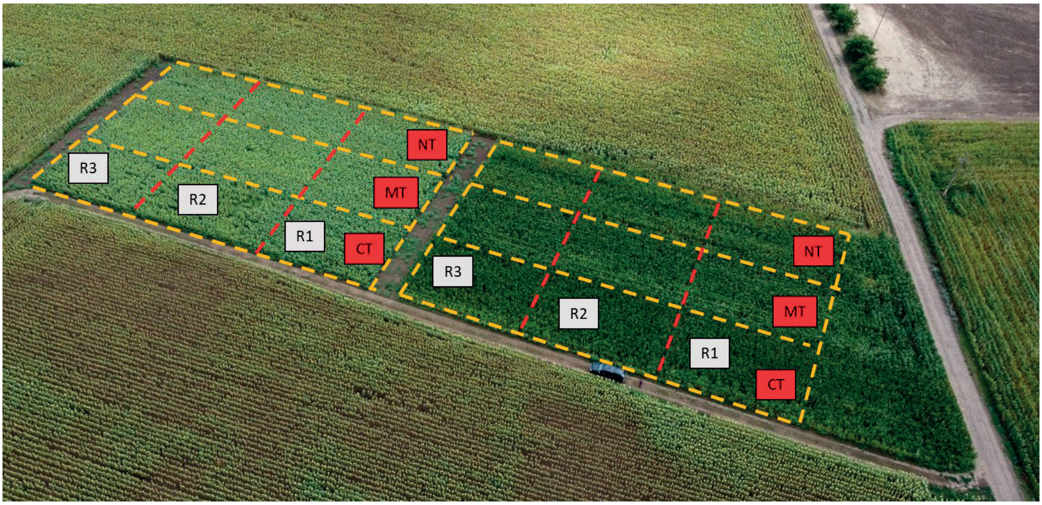


Figure 1. Experimental design on July 26th, 2024
(CT = Conventional tillage; MT = Minim tillage; NT = No tillage; R = Repetition)

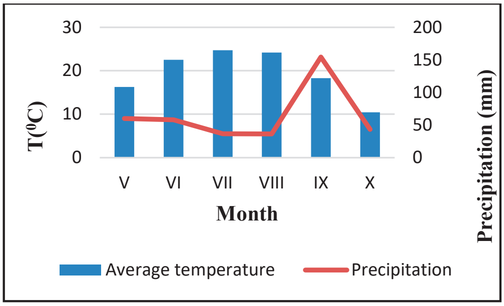


Figure 2. Precipitation amounts and mean monthly temperatures for April-October 2024

Experimental design and analysis of soil physical properties

Three treatments were used in this study, which was set up in a randomized block design: NT means direct seeding, MT with a chisel plow, and CT, whose soil was prepared with plow and two disk harrow passes at a depth of 0 to 30 cm and one plow pass. The sunflower hybrid HTS SUMIKO, from Syngenta was sown on April 30, 2024, in all three treatments at the time.

Soil penetration resistance (PR), hydraulic conductivity (Ks) were assessed in each tillage system in three different periods: sowing, vegetative period and harvest. For the PR, measurements were carried out with Eijkelkamp Penetrologger. It can measure depths of up to 80 cm and is equipped with a GPS system to quickly locate the measuring point. Measurements are taken directly in the field. Before the measurements start, a plan of the entire experimental field is drawn up, including all the variants of the experiment. Field measurements will begin once a working plan has been created using the penetrometer software. One of the parameters that should not be neglected in the measurements is the speed at which the penetrometer tip penetrates the soil, with the manufacturer recommending a speed of 2 cm/s. 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 and then flooded for the measurement. The Ks was calculated by Equation (1) (Lal R. et al., 2004, Eijkelkamp, 2017):

$$k = \frac{a \times 1}{A \times t} \times \ln\frac{h1}{h2}, \quad (1)$$

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); h1 and h2 are the water level at the start and end points of the measurements (cm). Spectrum Technologies Water Scout SM100 (Spectrum Technologies, Aurora, IL) were installed on May 31, 2024 at 10, 20 and 30 cm soil depths to monitor soil moisture. At a depth of 30 cm, SM300 sensors were used to measure, 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 WatchDog 1000 micro weather field station (Figure 3). Data were downloaded monthly to a 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 E_C <8 mS/cm and 0.5 - 80°C temperature range (Spectrum Technologies, 2019).

Figure 3. WatchDog 1000 Micro Weather Field Station with moisture sensor

The spectrum parameter extraction

Multispectral mapping of the experimental field was performed on 21 August 2024, using the DJI Mavic 3 Multispectral UAV. The obtained images were processed with Pix4D software, and vegetation index maps were created. The pixels inside the plot areas were averaged to calculate the VI. Lastly, Equation (2) was used to get the NDVI for both cameras (Rouse et al., 1973):

$$NDVI = (Rnir - Rred)/(Rnir + Rred) \quad (2)$$

where: Rnir, represents the near-infrared reflectance; Rred, the red reflectance.

To confirm whether the soil tillage systems under evaluation such as CT, MT, Or NT had an effect on plant growth and spectrum response, the NDVI was applied.

Assessment of grain production

At the physiological maturity stage (October 05, 2024), sunflower plants were harvested manually from an area of 10 m^2. This method was repeated three times for each system and repetition. Then, the following yield components number of head, number of achenes/head, diameter of head, 1000-Kernel Weight (1000-KW), Test Weight (TW), achene moisture content, and the grain yield (kg ha^{-1}) considering the moisture of 5.01%.

Statistical analysis

Analysis of variance (ANOVA), adapted to the randomized complete block design, was used to analyse the data obtained. Significant differences between treatments were calculated using the Tukey' test ($P<0.05$). Statistical analyses were carried out using SPSS 26. 0 for windows.

RESULTS AND DISCUSSIONS

Effects of tillage systems on soil physical properties

Soil hydraulic conductivity (Ks)

Table 1 indicates that the highest Ks values were recorded respectively under NT (1.90×10^{-2} cm/s) and MT (1.53×10^{-2} cm/s) at the same depth (0-10 cm) during the vegetative period. During the harvesting period, the highest values were still observed under the same systems, but this time at different depths (20-30 cm) for NT (1.83×10^{-2} cm/s) and (1.53×10^{-2} cm/s) associated at (10-20 cm) for MT. The lowest Ks values were recorded under the CT both during the vegetation stage and at harvest, at the same depth of (10-20 cm). A significant difference ($P<0.05$) exists between the different tillage systems studied.

Table 1. Effect of tillage on hydraulic conductivity (x 10^{-2} cm/s)

Tillage system	Depth (cm)	Ks sowing	Ks vegetation	Ks harvesting
NT	0-10	0.55 ±0.000 a	1.90 ±0.003 g	0.70 ± 0.001 c
	10-20	1.08 ±0.000 b	0.72 ±0.000 bc	1.45 ± 0.000 e
	20-30	1.33 ±0.000 c	1.57 ±0.001fg	1.83 ± 0.001 f
	30-40	1.71 ±0.000 d	0.35 ±0.001 ab	0.58 ± 0.006 bc
MT	0-10	0.55 ± 0.000 a	1.53 ±0.001 efg	0.66 ± 0.000 c
	10-20	1.18± 0.000 b	1.03±0.000 cd	1.53 ± 0.002 e
	20-30	1.33 ± 0.000 c	0.41 ±0.000 ab	1.08 ± 0.000 d
	30-40	1,71 ± 0,000 d	0.52±0.000 b	0.46 ± 0.000 abc
CT	0-10	0.55 ± 0.000 a	1.31 ±0.001 def	0.22 ± 0.000 a
	10-20	1.08 ± 0.000 b	0.10 ±0.000 a	0.24 ± 0.000 a
	20-30	1.33 ± 0.000 c	1.13±0.000 d e	0.32 ± 0.000 ab
	30-40	1.71 ± 0.000 d	0.42 ± 0.000ab	0.38 ± 0.000 ab
	P	0.000	0.000	0.000

a, b, c, d, e: Means for the same column with different letters are significantly different at the 5% threshold: $P<0.05$.

Volumetric soil water content (VWC)

The soil moisture progression trend in the experimental field was observed at three soil depths from May 31 to October 8, 2024 (Figure 4).

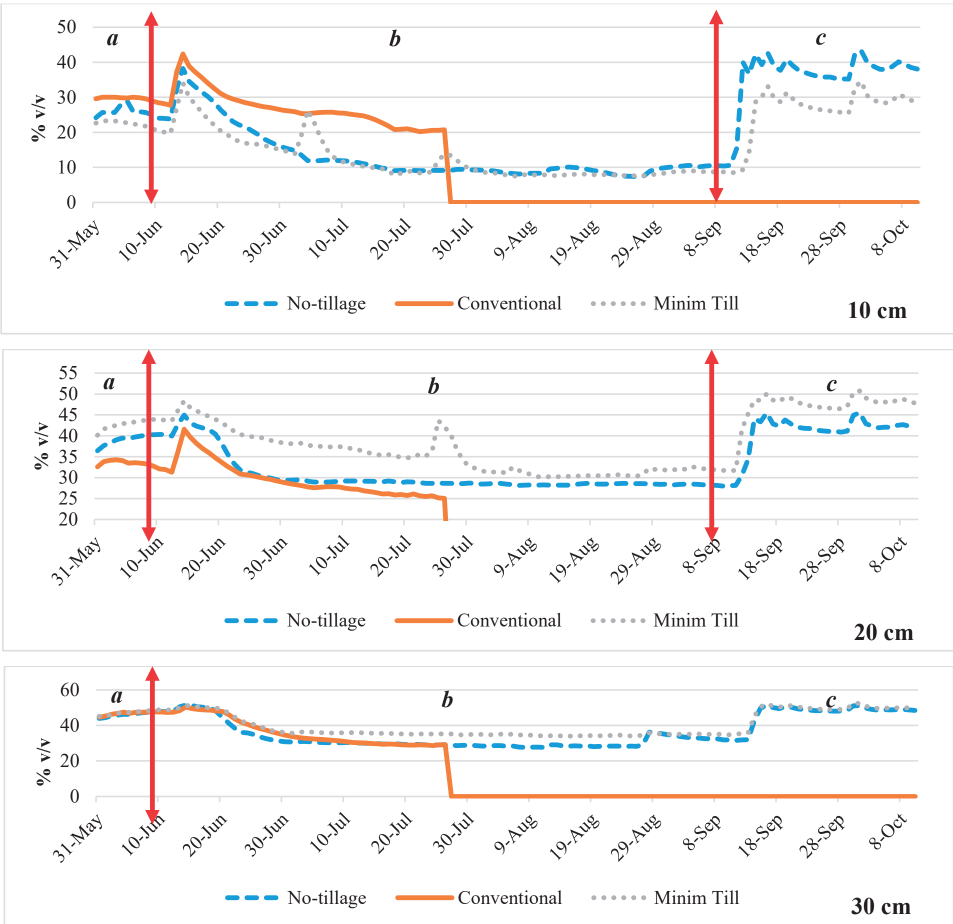


Figure 4. Effect of tillage systems on the volumetric soil moisture
(a = Sowing and emergence; b = Growing season; c = Maturity)

Soil electrical conductivity (Ec)

The SM300 sensors were installed in each tillage system at a depth of 30 cm to measure Ec. The results (Figure 5) show a significantly better Ec in the MT, with a maximum of 1.004 mS/cm reached on June 15, representing the beginning of the growth period, and a minimum of 0.325 mS/cm obtained on September 12, corresponding to the end of the growth period. On the other hand, the lowest EC values were recorded with NT. The lower Ec values recored under NT compared to CT and MT are could be due to differences in volumetric soil water content and evaporation rates. Endeed, NT maintains more stable soil water content levels, which conserves soil salinity, while CT increases evaporation resulting in decreased Ec. MT presents an intermediary environment that supports higher soil water content and root activity, which can justify the significant Ec values obtained especially in the vegetative stage.

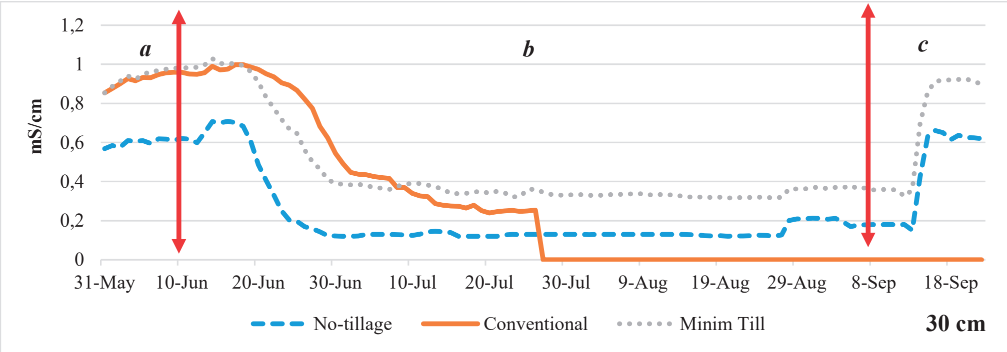


Figure 5. Effect of tillage systems on the soil electrical conductivity

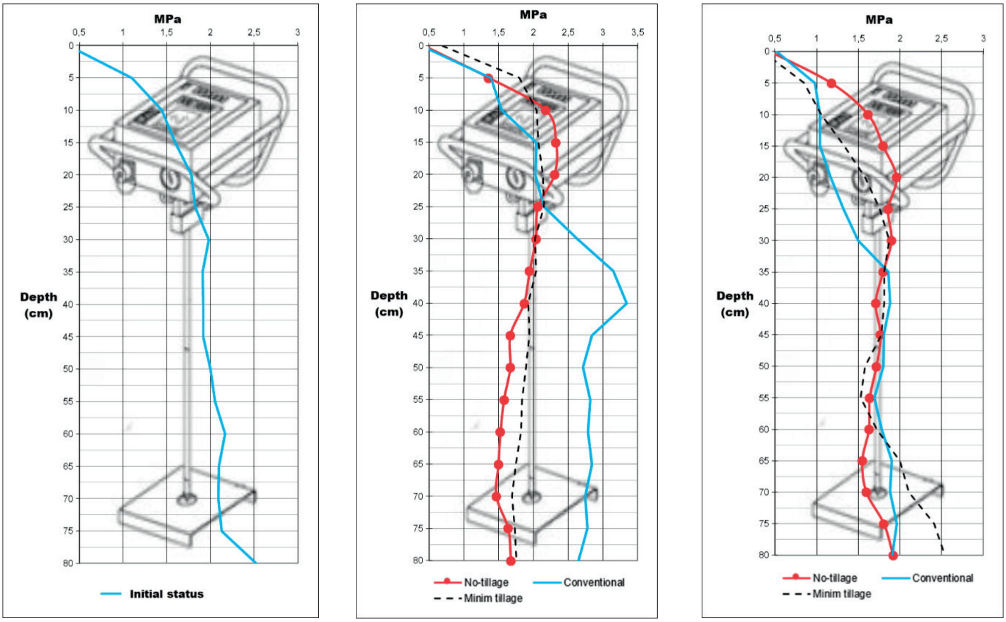
Penetration resistance (PR)

Results from the initial stage showed that PR values increased with soil depth, with minimum PR values observed at 0 to 5 cm and maximum values at a depth of 75 to 80 cm (Figure 6).

Based on results recorded during the vegetation stage of the sunflower crop over a depth interval of 0-80 cm (Figure 6).

Values in the NT range from a minimum of 0.42 MPa obtained at a surface depth of 0-5 cm to a maximum of 2.33 MPa obtained at a depth of 10-15 cm. In the MT, PR values oscillate between a minimum of 0.69 MPa and a maximum of 2.15 at depths of 0-5 cm and 20-25 cm, respectively. As for CT, the lowest PR value (1.39 MPa) is associated with the 0-5 cm depth, while the highest value (3.34 MPa) is associated with the 35-40 cm depth.

The results obtained during the harvesting stage showed that PR values did not increase as a function of soil depth, with the minimum PR values being observed at a depth of 0-5 cm and were (0.35 MPa) for MT; (0.45 MPa) for NT, and (0.52 MPa) for CT, respectively. The maximum values were obtained at different depths for each of the studied tillage systems. The maximum PR value in the NT (1.96 MPa) is associated with a depth of 15-20 cm. With MT, the maximum value (2.54 MPa) was observed at a depth of 75-80 cm. With CT, the maximum value (1.96 MPa) was recorded at depths of 70-75 cm (Figure 6).



Sowing *Vegetation stage* *Harvesting*

Figure 6. Effect of tillage systems on the penetration resistance

Influence of tillage systems on the spectral response of sunflower crop

The mean NDVI value indicates the mean state of health or vegetation cover in the area studied. NDVI values range from -1 to 1. Values between 0 and 1 indicate healthy, dense vegetation.

Values between 0 and -1 indicate sparse or affected vegetation.

Under the NT (Figure 7 a), the average NDVI value obtained is 0.536 and lies within the 0 to 1 interval, indicating average health and vegetation cover in the sunflower crop.

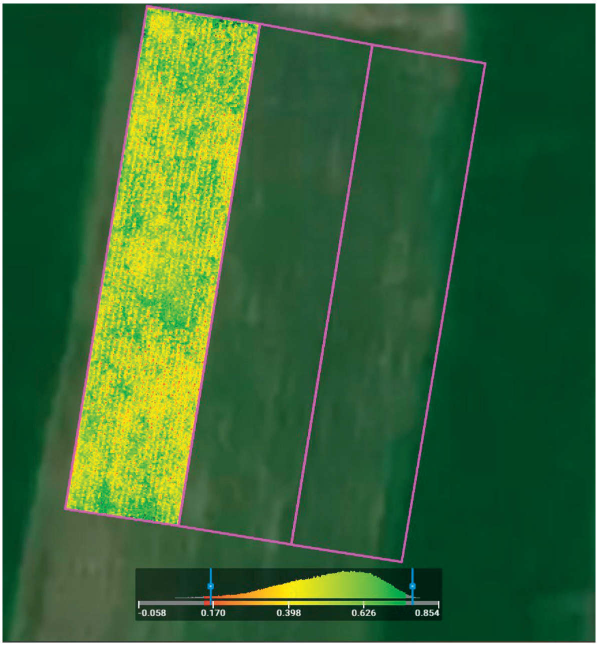
The mean NDVI value under the MT is 0.458 (Figure 7 b), which falls within the range of 0 and 1, but is lower than the mean NDVI of 0.536 observed under the NT.

This shows that the sunflower crop under the MT has slightly lower overall vegetation health than under the NT. NDVI values closer to 1 represent healthy vegetation, and this value (0.458) is below the tolerance threshold for moderate vegetation cover.

The mean NDVI value was 0.391 (Figure 7 c). This shows that the overall vegetation health of the sunflower crop under the CT is relatively poor.

An average NDVI of 0.391 is at the lower end of moderate vegetation health, indicating that the influence of tillage, modifying the physical properties of the soil, has also acted on the vegetation cover and/or vegetation of the sunflower crop.

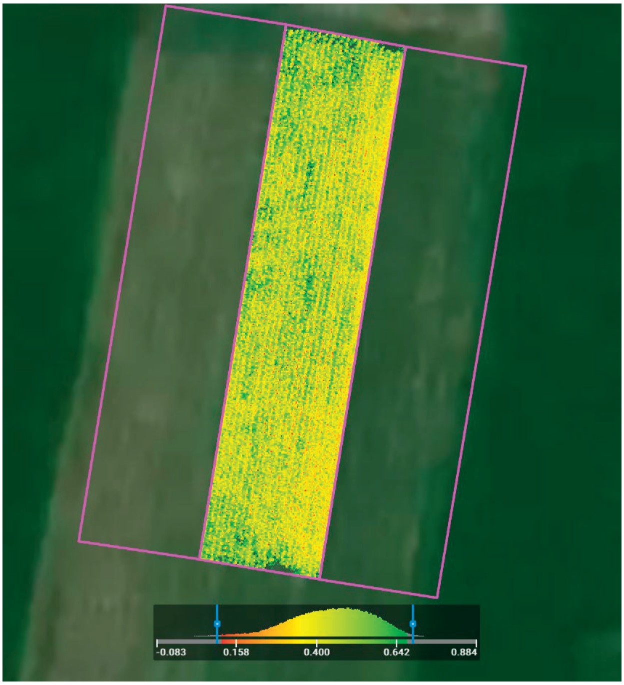
The cumulative results of the analyses show that the vegetation cover or condition of the sunflower vegetation under the CT is the lowest and, therefore, more affected than under the MT and NT.



Statistics

Layer area	999.846 m^2
Mean index	0.536
Index SD	0.136
Mean index (visible)	0.536
Index SD (visible)	0.128
Selected minimum value	0.141
Selected maximum value	0.752

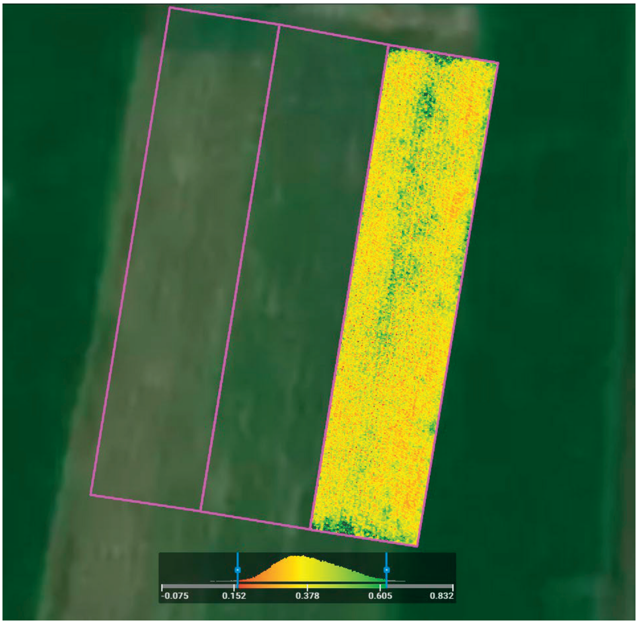
Figure 7 a. Effect of NT on the spectral response of sunflower crop



Statistics

Layer area	995.823 m^2
Mean index	0.458
Index SD	0.129
Mean index (visible)	0.452
Index SD (visible)	0.117
Selected minimum value	0.113
Selected maximum value	0.671

Figure 7 b. Effect of MT on the spectral response of sunflower crop



Statistics

Layer area	981.694 m^2
Mean index	0.391
Index SD	0.105
Mean index (visible)	0.389
Index SD (visible)	0.095
Selected minimum value	0.160
Selected maximum value	0.64

Figure 7 c. Effect of CT on the spectral response of sunflower crop

Effects of tillage systems on sunflower yield and yield components

The results obtained on yield parameters and sunflower yield show that, except for test weight (TW), tillage did not significantly influence the other parameters, which are 1000-Kernel weight (1000-KW) and WSH (weight of seed per head) (Table 2). The highest yield was obtained with CT. Between WSH and grain yield, there is a contrast whereby the weight of seed per head under NT is higher than that obtained under CT and inversely for yield. this contradiction can be explained by a higher plant density, which may lead to lower seeds per plant under NT, while the higher total yield in CT is due to a lower plant density but higher seeds, which contribute to a higher total yield.

Table 2. Effects of tillage systems on sunflower yield and yield components

Tillage system	WSH (g)	TW (kg/100 l)	1000-KW (g)	Yield (kg ha^{-1})
NT	113.59 ± 25.39a	41.82 ±0.15b	62.45 ±6.92a	2105
MT	95.82 ± 17.10a	40.51 ±0.34a	61.16 ±4.37a	2631
CT	101.91 ± 23.09a	43.08 ± 0.67c	55.85 ±7.19a	3052
P	0.621	0.000	0.446	-

a, b, c, d, e: Means for the same column with different letters are significantly different at the 5% threshold: P<0.05.

The influence of tillage systems on the physical properties of the soil, the spectral response and the yield of sunflowers were evaluated under the conditions of the Ezareni Research and Student Practice Station in Iasi. One of the properties studied was soil hydraulic conductivity (Ks). The results show that during the vegetation period and the harvesting phase, the highest value of Ks was obtained under NT (1.9 x 10^{-2} cm/s) and MT (1.5 x 10^{-2} cm/s) and at the same depth (0-10 cm). The difference in these results is that during the harvesting phase, the highest values were registered at a depth of 20-30 cm for the NT (1.8 x 10^{-2} cm/s), whereas with the MT (1.5 x 10^{-2} cm/s), they were recorded at 10-20 cm. The lowest Ks values were recorded under the CT both during the vegetation stage and at harvest at the same depth of (10-20 cm). A significant difference (P<0.05) exists between the different tillage systems studied. This highly low Ks observed under the CV is explained by the destruction of the earthworm community at ground level due to tillage. The presence of earthworms, combined with decomposing plant roots, creates macropores. These macropores cannot be preserved in plowed soils. This considerably reduces water movement from the surface to the topsoils (Burtan et al., 2020). On the other hand, they are well preserved in no-till soils. Hence, the high Ks values obtained under NT and MT. These results are similar to those obtained by Osunbitan et al. (2005), Green et al. (2003), Alvarez et al. (2009) who affirm in their research that although the volume of macropores generally represents only a small fraction of the soil volume, its contribution to the hydraulic conductivity of the soil is very high.

Considering all the soil depths studied, the most significant increase in VWC was recorded during the second half of September, culminating between 18 and 28 September 2024. Not only was this the period in which the highest amount of rainfall was recorded (154 mm), but it is also correlated with the plants maturity stage. At a depth of 0-10 cm, the highest value was reached under NT compared with MT and CT. This result is in accordance with that obtained by Agbede (2010), Salem et al. (2015) and Semenikhina (2020), who found that the most significant VWC values were obtained under the NT. The results for depths of 10-20 cm and 20-30 cm show a higher value of VWC under the MT system. These results confirm those obtained by Ozgoz et al., (2007), who indicate in their studies that the VWC increases significantly under the MT system in their studies.

The Ec values obtained under NT are significantly lower than those recorded under CT and MT at a depth of 0-30 cm. This result is similar with that obtained by Lilienfein et al (2000). This shows that the Ec is lower under the NT and higher under the CT. This can be explained by the hypothesis that nutrient runoff is more intensified under NT than under CT. Significant Ec values were obtained on the MT, particularly during the vegetation phase starting at the beginning of July, when a decrease was observed under the CT, whereas under the NT the values remained constant during the same period.

Penetration resistance is a widely measured physical property of soil, as it represents a reliable method of assessing soil strength. Penetration resistance (PR) varies from one tillage system to another. Soil penetration resistance for the three tillage treatments increased with depth. Detailed analysis of each period of the plant cycle reveals some significant differences. Penetration resistance at a depth of 0 to 25 cm was higher under NT than under MT and CT. However, from a depth of 25 cm to 80 cm, resistance to penetration decreased, which coincides with its increase under the other two systems, MT and CT, where a highly significant difference was noted. On the one hand, this result confirms those of several authors who have stated in their studies that resistance to penetration is reduced in CT compared with NT (Sidiras et al., 2000; Taser and Metinoglu, 2005; Vakali et al., 2011; Afzalinia and Zabihi, 2014, Salem et al., 2015; Burtan et al., 2020; Martins et al., 2021) and on the other hand, these results are also in line with those obtained by, who have shown in their research that when resistance to penetration decreases in NT, it increases in the other systems (Osunbitan et al., 2005; Mihu et al., 2022).

The results of the NDVI spectral response analysis of sunflower showed a significant difference between the three systems studied (NT>MT>CT). These results contradict those obtained by Martin et al. (2021) in their study, in which they found no significant difference between the treatments evaluated (NT, MT, CT) in terms of spectral response and bean growth. According to the author, this may be associated with the low value obtained at PR not reaching the limit to affect root development. Leite et al. (2012) in their study, after evaluating four different types of tillage systems, the author observes a significant difference in the spectral response of NDVI on bean crops. The author claims that this difference is due to the high PR values obtained under NT and MT.

Similar high PR values were also recorded in our study under NT and MT, which justifies the significant difference noted between the treatments evaluated on the spectral response through NDVI of the sunflower crop.

In addition to PR, SWC also represents a factor influencing plant growth and vegetation and, contributing to the significant difference in results obtained.

The tillage system effect was significant on TW, under CT, where the highest values were reached. On the other hand, there was no significant difference between 1000-Kernel weight (1000-KW) and WAC.

A significant difference was recorded in sunflower grain yield between the three systems studied, and the highest yield was obtained under CT. This result is confirmed by several authors who have shown that yield production is high under CT. However, the low yields obtained under all three tillage systems were due to the low rainfall recorded during the experiment.

CONCLUSIONS

A short study was carried out on the influence of three different soil systems on their physical properties and spectral response on sunflower production. The results obtained during this study indicated that Ks, PR and VWC performed most significantly and had the highest values under NT. However, a specific point can be observed at depths of 10-20 cm and 20-30 cm, where the highest values (50.74% v/v) and (52.25% v/v) were obtained under MT. Also, the PR values obtained (3.34 MPa) under CT (2.33 MPa) under NT, and, especially during the vegetative period, being above the threshold (2.5 MPa), could influence sunflower crop growth and yield. On the contrary, conventional tillage practices increased the Ec, and the highest values were recorded under this system. In terms of the spectral response of the crop through NDVI, there was a significant effect between the tillage systems studied. Regarding sunflower grain yield, a significant influence was observed between the three tillage systems evaluated, with a high yield under CT.

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