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# Influence of primary tillage methods on the development of productive moisture reserves before sunflower sowing in the conditions of the Right-Bank Forest-Steppe of Ukraine

**Abstract.** The preservation and efficient use of productive moisture is one of the determining factors for stable sunflower production in conditions of unstable moisture and precipitation deficiency. The purpose of the study was to establish the influence of the method and depth of the primary tillage on the reserves and vertical distribution of productive moisture in typical chernozem before sowing sunflower in the conditions of the Right-Bank Forest-Steppe of Ukraine. The study was conducted in 2022-2026 in a stationary field experiment of the Department of Arable Farming and Herbology at the National University of Life and Environmental Sciences of Ukraine. The treatments comprised deep mouldboard tillage to a depth of 25-27 cm, deep non-mouldboard tillage to 25-27 cm, and shallow non-mouldboard tillage to 14-16 cm. Productive moisture reserves were determined in the 0-100 cm soil layer according to the generally accepted method. It was established that the method and depth of the primary tillage affected the total supply and vertical distribution of productive moisture. The highest mean reserve of productive moisture in the 0-100 cm soil layer over the study period was recorded under deep non-mouldboard tillage at 25-27 cm, amounting to 214 mm, compared with 204 mm under mouldboard tillage and 191 mm under shallow non-mouldboard tillage at 14-16 cm. The most pronounced advantage of deep non-mouldboard tillage was observed in 40-60 and 60-100 cm soil layers. Correlation and regression analysis revealed a weak positive relationship between the sum of precipitation in the autumn-winter period and the reserves of productive moisture, while the coefficient of determination was 0.0845 for deep mouldboard, 0.0377 for deep non-mouldboard, and 0.1885 for shallow non-mouldboard. The results obtained proved the feasibility of using a 25-27 cm deep non-mouldboard

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tillage to increase the accumulation and preservation of productive moisture in the soil before sowing sunflower seeds

**Keywords:** typical chernozem; deep loosening; autumn-winter precipitation; water regime of the soil; disk cultivation; ploughing

## INTRODUCTION

Contemporary hydrometeorological conditions are characterised by significant changes that directly affect the functioning of agroecosystems, create new challenges for agriculture, and determine the relevance of research on effective ways to overcome them. Sharp fluctuations in the temperature regime and variegated distribution of precipitation during the growing season of field crops are a determining factor in the development of their final productivity. Therefore, according to R.K. Srivastava (2025), agricultural practices should primarily be aimed at optimising the reserves of productive moisture in the soil and its physical and chemical parameters, which is the basis for the development of an adequate resource potential of crop yields. The results of contemporary research indicate that one of the key links of the farming system, which significantly affects the reserves of productive moisture in the soil, is the system of its cultivation. M. Adil *et al.* (2026) stressed that the primary tillage is crucial in this regard, which in most cases determines the ability to accumulate moisture in the meter-long soil thickness during the autumn-winter period and determines its initial reserves for the period of sowing spring or during the spring resumption of vegetation of winter crops, and the effectiveness of its use by plants throughout the growing season.

Primary tillage is one of the most important stages of the technology of growing agricultural crops, since it primarily affects its structure, on which other agrophysical and hydrophysical properties of the soil will depend. According to S. Mondal & D. Chakraborty (2022), minimising primary tillage has a positive effect on soil agrophysical and water parameters, but this issue remains controversial in the scientific community due to the availability of conflicting data. Therefore, in the context of the current climate challenges, the substantiation of the optimal option for primary tillage is of particular relevance. The issue under study is also gaining development in Ukraine, as there is an increase in the number of dry years, which requires improving approaches to the selection of the primary tillage. O.I. Tsyliuryk *et al.* (2025) pointed out the need for active introduction of resource-saving technologies to optimise the use of productive moisture by plants from the soil. Similar conclusions were drawn by A. Tereshchenko & A.M. Tarabrina (2025) and S. Shevchenko *et al.* (2025), confirming the significant effect of the primary tillage on the ability of the soil to accumulate productive moisture from precipitation.

Given the above, the influence of the primary tillage on the nature of accumulation and distribution of precipitation moisture in the soil is not sufficiently studied, which determines the need for comprehensive research on this problem. The purpose of the study was to find out the features of the development of productive moisture reserves in typical chernozem, depending on the method and depth of the primary tillage in the conditions of the Right-Bank Forest-Steppe of Ukraine. To achieve this goal, it was planned to determine the patterns of moisture distribution along the soil profile, evaluate the effectiveness of precipitation accumulation in the autumn-winter period, and scientifically substantiate the best option for primary tillage to preserve soil moisture.

## LITERATURE REVIEW

Contemporary agriculture is significantly affected by climate changes, which are manifested due to sharp temperature fluctuations and uneven distribution of precipitation. This can lead to unproductive moisture losses from the soil, which often coincide with critical periods of crop development. P. Sharma *et al.* (2024) noted that to ensure better conditions for plant ontogenesis, it is important to apply innovative sustainable agricultural technologies aimed at improving the water retention capacity of the soil. In this context, H. Zheng *et al.* (2024) confirmed that differentiation of cultivation can contribute to better accumulation of productive moisture in the soil. The process of forming soil moisture reserves is caused by two factors. The first of which is precipitation, the volume of which cannot be regulated; the second – hydrophysical properties of the soil and the content of organic matter in it, which can be directly regulated, in particular through tillage. The method and depth of the primary tillage determine such agrophysical parameters as density, porosity, and water permeability, which will affect the accumulation of productive moisture and its consumption by the crop (Sairam *et al.*, 2023). T. Laxman *et al.* (2024) noted that it is the use of soil protection treatment that contributes to improving the structure of the soil and increasing its water retention capacity, more efficient use of precipitation, and creating favourable conditions for the growth and development of agricultural crops. Thus, C. Pirlot *et al.* (2024) found that the level of accumulation of productive moisture is determined not only by the selected farming system, but also by the duration of its application, since the positive impact of soil protection technologies on the water regime of the soil is gradually manifested. M. Adil *et al.* (2024) pointed out that the use of No-till technology improves precipitation accumulation in the soil and directly leads to an increase in crop yields. It was also found that variants with the remaining nutrient residues showed the highest yield results.

According to K. Nthebere *et al.* (2024) and A.B. Irkiso *et al.* (2025), the effectiveness of minimum and zero treatment is most evident when they are used systematically over a long period of time. At the initial stages of the transition to soil protection technologies, a certain compaction of the surface layer of the soil and a slight decrease in the productivity of individual crops were possible. However, in the future there is a gradual improvement in the structural state of the soil, the content of organic matter increases, the stability of soil aggregates increases, and the hydrophysical properties improve, which contributes to more efficient accumulation and preservation of productive moisture. That is why the long-term use of soil protection farming technologies is considered as one of the most promising areas for adapting agricultural production to current climate challenges and increasing the resistance of agroecosystems to moisture deficiency. The analysis of scientific literature indicates that there is no consensus on the advantages of certain methods of primary tillage. The finding of W. Hassan *et al.* (2022) showed that the effectiveness of No-till and fine cultivation technologies in comparison with traditional ploughing varies significantly depending on the natural and climatic conditions, the granulometric composition of the soil, the amount of precipitation, the crop grown, and the duration of application of a particular technology. If in arid regions, soil protection systems mainly provide better accumulation of productive moisture, then in conditions of sufficient moisture, their advantages are often less pronounced or completely absent. The vast majority of contemporary studies were conducted in China, the United States of America, Canada, Australia, and India, where the soil and climatic conditions differ significantly from those of Ukraine. Differences in soil types, precipitation, temperature conditions, and farming patterns make it difficult to directly transfer the results to the chernozems of the Right-Bank Forest-Steppe (Adil *et al.*, 2024; Clement *et al.*, 2024; Sojnóczki *et al.*, 2024). In this regard, there is a need to conduct regional studies aimed at establishing patterns of development of productive moisture reserves specifically for the soil and climatic conditions of Ukraine.

Previous studies, including those conducted by researchers from the Department of Arable Farming and Herbology at the National University of Life and Environmental Sciences of Ukraine (NULES of Ukraine), V.O. Gurtovenko & O.A. Tsiuk (2023; 2024), established that changing the method of primary tillage significantly affects the density of the structure, structural state, hydrophysical properties, and the value of productive moisture reserves of typical chernozem. The use of deep non-mouldboard loosening ensured the development of more favourable agrophysical conditions and increased the accumulation of productive moisture compared to shallow tillage. Similar conclusions on the need to adapt the primary tillage technologies to specific soil and climatic conditions of Ukraine were outlined by S. Dolia & M. Shevchenko (2024), M.M. Ptashnik *et al.* (2026), who noted that optimisation of the primary tillage is one of the effective reserves for improving the efficiency of using natural moisture and stabilising the yield of field crops. Thus, the generalisation of the results of contemporary research showed that the system of primary tillage is one of the determining factors for regulating its water regime and the development of productive moisture reserves. Simultaneously, the ambiguity of the results obtained in various natural and climatic conditions and the insufficient number of comprehensive studies performed for the chernozems of the Right-Bank Forest-Steppe of Ukraine make it necessary to further investigate the features of the accumulation of productive moisture depending on the method and depth of the primary tillage and weather conditions of the year.

## MATERIALS AND METHODS

The study was conducted in 2022-2026 in a stationary field experiment established in 2001 by the Department of Arable Farming and Herbology of the National University of Life and Environmental Sciences of Ukraine, at the Agronomic Research Station, a separate subdivision of NULES of Ukraine (Pshenychne village, Bila Tserkva district, Kyiv region). During the entire period of operation of the stationary experiment, the variants of the primary tillage were assigned to the same experimental sites, which allowed assessing the long-term impact of different methods and depth of the primary tillage on the development of productive moisture reserves. Weather conditions were characterised using data from the meteorological station of the Agronomic Research Station, a separate subdivision of NULES of Ukraine, and archival data from the Meteopost (n.d.) service. The soil of the experimental field was typical chernozem. The humus content in the arable soil layer was 4.05-4.38%, the reaction of the soil solution (pH of salt extract) was 6.9-7.3, and the cationic exchange capacity was 32 mg-eq. per 100 g of soil. Ground water was at a depth of 5-6 m, which excluded its direct influence on the development of productive moisture reserves in 1 metre soil layer. The total moisture capacity of the soil was 38.4-42.75%, the field moisture capacity was 28.2%, and the capillary rupture humidity was 19.7%.

The experiment was conducted under a stationary five-field crop rotation (winter wheat – sunflower – spring barley – grain maize – soybean), deployed over time and space. The experiment was based on the method of systematic placement of variants in four-fold repetition. The experiment scheme included three variants of primary tillage: deep mouldboard (25-27 cm), deep non-mouldboard (25-27 cm), and shallow non-mouldboard (14-16 cm). The area of one sown plot was 96 m² (12 × 8 m). The total area of the experimental plots where soil samples were recorded and selected was 1,152 m² (0.1152 ha). The total area of the stationary field experiment was 0.30 ha, which included experimental plots with other research options, protective strips, and technological passages.

The object of research was the influence of variants of the primary tillage of different methods and depth on the development of reserves of productive moisture of typical chernozem. The predecessor of sunflower was winter wheat. After harvesting, stubble peeling was performed twice (disking in two tracks), after which the primary tillage was carried out in accordance with the experiment scheme. The studied variants of the primary tillage were performed by the following units: deep mouldboard (control) – with a rotary plough PO-3-35; deep non-mouldboard – with a chisel with a deep digger AGR-1,7; and shallow non-mouldboard – with a heavy disc harrow BDVP-4,2. The actual depth of cultivation was monitored by field measurements during technological operations. In the spring, moisture was closed with BR-6 rotary harrows on all variants of the experiment, and immediately before sowing sunflower seeds, pre-sowing cultivation was carried out with a Carrier 420-820 disk cultivator to the depth of seed embedding. Sunflower hybrid 'Sumiko HTS', recommended for growing in all soil and climatic zones of Ukraine, was sown. Sowing was carried out after the soil reached the optimal temperature for seed germination. The seeding rate was 65 thousand germinating seeds per 1 ha. The fertiliser system provided for the introduction of 100 kg/ha of urea for pre-sowing cultivation and 100 kg/ha of nitroammofoska during sowing. Crop protection included the introduction of soil herbicide Primextra TZ Gold

(S-metolachlor, 312.5 g/L + terbutylazine, 187.5 g/L at a rate of 4.5 L/ha, and if necessary, depending on the species composition and degree of contamination of crops, the herbicide Granstar Gold (tribenuron-methyl, 562.5 g/kg) + tifensulfuron-methyl, 187.5 g/kg) and graminicide Fusilad Forte (fluazifop-P-butyl, 150 g/L). Before flowering, treatment with the fungicide Amistar Gold (azoxystrobin, 125 g/L + difenoconazole, 125 g/L) was carried out at a rate of 1.0 L/ha and foliar application of boron-containing microfertiliser (150 g B/ha).

Before sowing sunflower seeds in each year of research, soil samples were taken to determine the productive moisture reserves. The sampling was carried out in all four repetitions of the field experiment using a Kaczynski drill. Samples were taken in the central part of the accounting area, retreating from its edges by 0.5-1.0 m, which minimised the edge effect. The selection was carried out in layers to a depth of 100 cm (0-10, 10-20, 20-30, 30-40, 40-60, 60-80, and 80-100 cm). Soil moisture was determined by the gravimetric (thermostatic-weight) method in accordance with the requirements of DSTU ISO 16586:2005 (2008) by drying the samples to a constant weight at a temperature of 105°C. Weighing was performed on electronic laboratory scales with an accuracy of 0.01 g. Productive moisture reserves were calculated using the equation:

$$W_{prod} = \frac{(X - X_{FC}) \times d \times h}{10}, \tag{1}$$

where $W_{prod}$ – productive moisture reserve, mm; $X$ – actual soil moisture, % to absolutely dry soil; $X_{FC}$ – humidity of persistent wilting plants; %; $d$ – volume weight of soil; g/cm³; $h$ – thickness of the test soil layer, cm.

The results shown in the tables are the arithmetic mean values of four independent repetitions of the field experiment. To characterise the humidification conditions, the sum of precipitation in the autumn-winter period was used, since it is at this time that the main part of the reserves of productive moisture in the soil profile is formed. Statistical processing of experimental data was performed using variational statistics using variance (ANOVA), correlation, and regression analysis. Two-factor dispersion analysis was used to assess the influence of the method of primary tillage, the year of research, and their interaction on the development of productive moisture reserves. The reliability of differences between the average values was estimated by the least significant difference ($LSD_{0.05}$) at the significance level $p \leq 0.05$. Correlation analysis was performed using the Pearson correlation coefficient, and regression analysis was used to estimate the relationship between the amount of precipitation in the autumn-winter period and the reserves of productive moisture in 1 metre soil layer. Calculations were performed using Microsoft Excel and Statistica 10 software suites. The study was conducted in accordance with the principles of responsible use of natural resources set out in the Convention on Biological Diversity (1992).

## RESULTS

The value of productive moisture reserves in the soil is largely formed due to precipitation during the autumn-winter period, since it is at this time that the low intensity of evaporation contributes to its maximum accumulation in the soil profile. With this in mind, it is advisable to use the period from October to March for an objective analysis of the accumulation of productive moisture (Fig. 1).

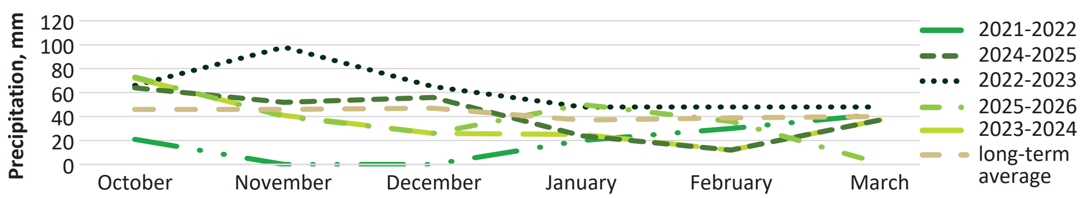


**Figure 1.** Amount of precipitation during the autumn-winter period (October-March) during the research years

**Source:** compiled by the authors

Analysis of precipitation during the autumn-winter period indicates a significant variability in humidification conditions during the years of research. The least favourable distribution of precipitation was the period 2021-2022, which was characterised by a low amount of precipitation in November-December and February. This nature of precipitation distribution limited the ability to replenish moisture reserves in the soil in the autumn-winter period. In 2022-2023, the lowest amount of precipitation among the main years of research was noted – 113 mm, which was 142 mm (55.7%) less than the long-term average (255 mm). The greatest amount of precipitation fell in October-November, while in December-March their intake was significantly lower. The wettest period was 2023-2024, when the amount of precipitation was 373 mm, which was 118 mm (46.3%) higher than the long-term average. Compared to other years, during this period, precipitation was more uniform during the autumn-winter months, which created more favourable conditions for the development of productive moisture reserves in the soil profile. In 2024-2025 and 2025-2026, the amount of precipitation was 213 and 226 mm, respectively, that is, it was 42 and 29 mm lower than the long-term average. Furthermore, their monthly distribution was significantly different: in 2024-2025, a significant part of precipitation occurred in October-December, while in 2025-2026, there was relatively more precipitation in January-February. Thus, over the years of research, contrasting conditions of atmospheric humidification were formed, which was reflected in the further variability of productive moisture reserves before sunflower sowing. Analysis of productive moisture reserves in 1 metre soil layer before sunflower sowing showed the influence of the primary tillage method on the accumulation and distribution of moisture along the profile (Table 1).

**Table 1.** Productive moisture reserves in a 0-100 cm layer depending on the primary tillage variant, mm

| Year | Deep mouldboard (25-27 cm) | Deep non-mouldboard (25-27 cm) | Shallow non-mouldboard (14-16 cm) | $LSD_{0.05}$ |
|---|---|---|---|---|
| 2022 | 165 | 172 | 160 | 3.87 |
| 2023 | 192 | 196 | 188 | 4.76 |
| 2024 | 212 | 216 | 208 | 4.8 |
| 2025 | 218 | 230 | 208 | 5.1 |
| 2026 | 232 | 258 | 189 | 5.3 |
| Average | 204 | 214 | 191 | – |

**Source:** compiled by the authors

It was found that during the entire research period, the largest reserves of productive moisture were formed during deep non-mouldboard tillage, where they varied from 172 to 258 mm, while for deep non-mouldboard – from 165 to 232 mm, and for shallow non-mouldboard – from 160 to 208 mm. Thus, deep non-mouldboard tillage provided additional accumulation of moisture available to plants in the range of 20-30 mm compared to mouldboard, and 35-50 mm compared to shallow non-mouldboard. Analysis of the long-term average data for 2022-2026 indicators of the vertical distribution of productive moisture reserves in the typical chernozem profile indicated the dependence of its accumulation on the method and depth of the primary tillage (Table 2).

**Table 2.** Vertical distribution of productive moisture reserves in the typical chernozem profile depending on the primary tillage variant (average for 2022-2026), mm

| Soil layer, cm | Deep mouldboard (25-27 cm) | Deep non-mouldboard (25-27 cm) | Shallow non-mouldboard (14-16 cm) | $LSD_{0.05}$ |
|---|---|---|---|---|
| 0-10 | 20 | 15 | 17 | 3.9 |
| 10-20 | 22 | 25 | 20 | 4.2 |

Table 2, Continued

| Soil layer, cm | Deep mouldboard (25-27 cm) | Deep non-mouldboard (25-27 cm) | Shallow non-mouldboard (14-16 cm) | $LSD_{0.05}$ |
|---|---|---|---|---|
| 20-30 | 24 | 26 | 23 | 4 |
| 30-40 | 25 | 29 | 27 | 4.4 |
| 40-60 | 37 | 42 | 31 | 4.8 |
| 60-80 | 40 | 37 | 30 | 4.7 |
| 80-100 | 36 | 40 | 43 | 4.9 |
| 0-100 | 204 | 214 | 191 | – |

**Source:** compiled by the authors

In general, the highest reserves of productive moisture in a 0-100 cm soil layer were recorded for deep non-mouldboard tillage, where they amounted to 214 mm, while for shallow non-mouldboard tillage (disking by 14-16 cm) this indicator was lower and amounted to 191 mm. The greatest differences between the variants of the experiment were observed in the lower part of the arable and sub-arable soil layers. In a 40-60 cm soil layer, 42 mm of productive moisture accumulated in a deep non-mouldboard variant, which is 5 mm more compared to deep mouldboard tillage and 11 mm more compared to shallow non-mouldboard. In a 60-80 cm soil layer, the highest reserve of productive moisture was recorded in the conditions of mouldboard tillage, where it was 40 mm, while in chisel and shallow non-mouldboard tillage, this indicator was 38 and 31 mm, respectively. In a 80-100 cm soil layer, the highest reserve of productive moisture was recorded for shallow non-mouldboard tillage (43 mm), which exceeded the corresponding indicators for mouldboard and deep non-mouldboard tillage by 8 and 3 mm, respectively. During this treatment, 40 mm of productive moisture accumulated in this layer. In the upper 0-10 cm soil layer, the greatest reserve of productive moisture was recorded in the conditions of deep mouldboard tillage, where it was 20 mm, while in the conditions of shallow non-mouldboard and deep non-mouldboard tillage, this indicator was 17 and 15 mm, respectively. In 10-20 and 20-30 cm soil layers, on the contrary, the advantage was deep non-mouldboard tillage, in which the reserves of productive moisture were 25 and 26 mm, respectively, compared to 22 and 24 mm for mouldboard and 20 and 23 mm for shallow non-mouldboard tillage. Thus, the results obtained indicate differences not only in the total accumulation of productive moisture, but also in the nature of its vertical distribution along the soil profile. Deep non-mouldboard tillage provided the largest total supply of productive moisture in a 0-100 cm layer, while mouldboard and shallow non-mouldboard tillage was characterised by a more pronounced accumulation of moisture in individual horizons. To assess the nature of the dependence of productive moisture reserves on the amount of precipitation in the autumn-winter period, a correlation and regression analysis was performed separately for each method of primary tillage (Fig. 2).

A positive but weak relationship was established between the studied indicators for all tillage options. For deep mouldboard tillage, the coefficient of determination was $R^2 = 0.0845$, for deep non-mouldboard tillage – $R^2 = 0.0377$, and for shallow non-mouldboard tillage – $R^2 = 0.1885$. Thus, the amount of precipitation in the autumn-winter period explained 8.45%, 3.77%, and 18.85% of variations in productive moisture reserves in 1 metre soil layer, respectively. In all cases, the regression coefficients had a positive value, which indicates a general trend towards an increase in productive moisture reserves with an increase in precipitation. However, a small number of independent annual observations ($n = 5$) limited the statistical power of the correlation and regression analysis performed, so the established dependencies should be considered primarily as trends.

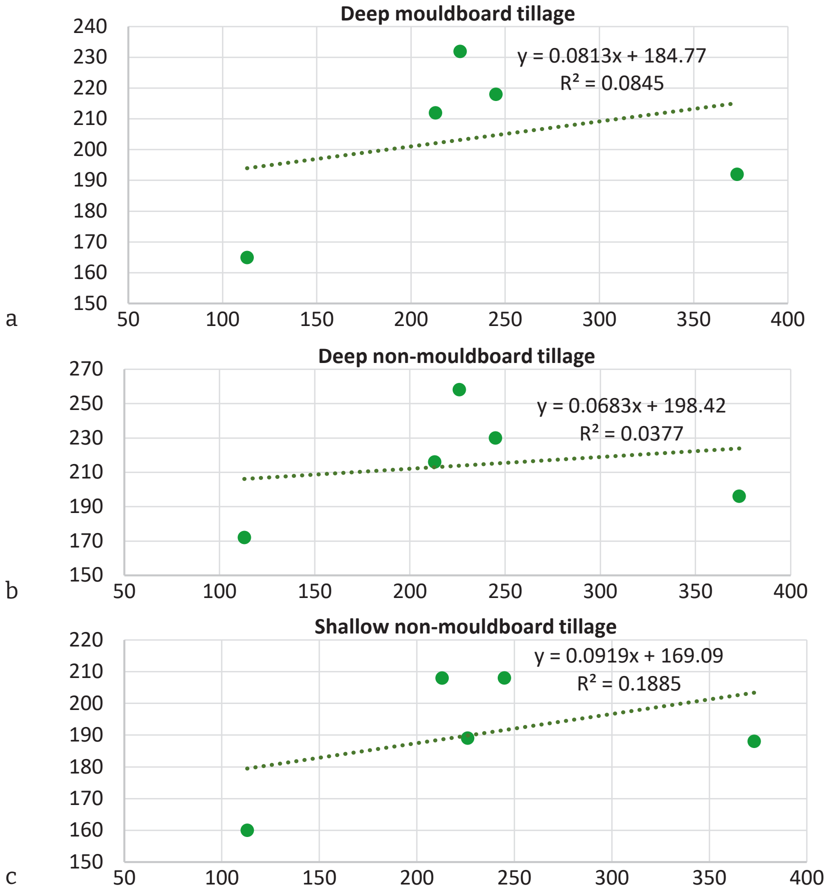


**Figure 2.** Correlation between the amount of precipitation in the autumn-winter period and the reserves of productive moisture in a 0-100 cm soil layer

**Note:** a – deep mouldboard tillage (25-27 cm); b – deep non-mouldboard tillage (25-27 cm); c – shallow non-mouldboard tillage (14-16 cm)

**Source:** compiled by the authors

## DISCUSSION

The results obtained confirmed the significant interannual variability of weather conditions in the autumn-winter period and their important role in the development of productive moisture reserves in the soil before sunflower sowing. The established differences in the amount and nature of precipitation distribution over the years of research created contrasting moisture conditions, which allowed assessing the influence of primary tillage methods on the efficiency of moisture accumulation and preservation. Similar patterns were noted in the recent studies by M. Adil *et al.* (2024) and C. Pirlot *et al.* (2024), who showed that the amount of precipitation during the cold period is one of the determining factors for the development of productive moisture reserves, while the efficiency of its accumulation and preservation largely depends on the agrophysical state of the soil and the primary tillage system. However, the results of the study suggest that the influence of precipitation on the development of productive moisture reserves is not unambiguous and is largely determined by their internal seasonal distribution. Thus, even with a low amount of precipitation close to the long-term average, their intake during periods when the soil can effectively accumulate and retain water can provide more favourable conditions for the development of moisture reserves. On the contrary, a significant amount of precipitation that occurs unevenly or during periods of low soil infiltration capacity is not always transformed into a corresponding increase in productive moisture reserves. Thus, the data obtained are consistent with current ideas that the development of productive moisture reserves is the result of the interaction of weather conditions and soil properties, and the efficiency of using precipitation can vary significantly depending on the method of primary tillage. In this context, it is particularly important to compare the established patterns with the findings of other researchers regarding the influence of various tillage systems on the accumulation and preservation of moisture.

The results obtained showed that the method of primary tillage affects not only the total amount of accumulated productive moisture, but also its redistribution in the soil profile. The largest average supply of productive moisture in the 0-100 cm soil layer was formed during deep non-mouldboard tillage and amounted to 214 mm, which was 10 mm higher than for mouldboard tillage and 23 mm higher for shallow non-mouldboard tillage. This indicates the highest ability of deep non-mouldboard tillage to ensure the accumulation and preservation of productive moisture in the entire soil layer under study. The obtained patterns are generally consistent with the results of O.E. Elabbadi *et al.* (2024), M.M. Modiba *et al.* (2024) and M. Diop *et al.* (2024), who noted the positive effect of deep non-mouldboard tillage on the accumulation and preservation of productive moisture. The researchers attributed the advantage of this method of cultivation to the preservation of the natural structure of the soil, improving its pore space and water permeability, which contributes to the penetration of precipitation into deeper horizons. Simultaneously, the results of this study showed that the advantage of individual cultivation methods was not the same in all layers of the soil profile. In particular, in the 0-10 cm layer, the highest moisture reserve was formed during deep mouldboard tillage, while in the 10-20 and 20-30 cm layers, the maximum values were obtained for deep non-mouldboard tillage. This may indicate a different nature of water redistribution depending on the depth and method of mechanical impact on the soil. Especially significant were the results in a 40-60 cm layer, where 42 mm of productive moisture accumulated during deep non-mouldboard tillage, compared to 37 mm for mouldboard and 31 mm for shallow non-mouldboard tillage. This is probably conditioned by the creation of more favourable conditions during chisel cultivation for vertical movement of water deep into the soil profile without forming a continuous compacted layer, which can limit infiltration. In a 80-100 cm layer, the greatest reserve of productive moisture, on the contrary, was obtained with shallow non-mouldboard tillage – 43 mm. This pattern indicates that it is impractical to evaluate the effectiveness of the main cultivation methods only by the indicators of individual horizons.

In this study, it was the total moisture reserve in the 0-100 cm layer that allowed establishing the advantage of deep non-mouldboard tillage, while shallow non-mouldboard tillage was characterised by a significant accumulation of moisture in the deepest layer under study. Thus, the results obtained confirm that deep non-mouldboard tillage creates more favourable conditions for the development of a total supply of productive moisture in a 1 metre layer of typical chernozem, but the nature of its vertical distribution depends on the specific soil layer. The established patterns are consistent with the results of M. Ahmad *et al.* (2018), who reported that chisel treatment improves water infiltration and moisture redistribution in the soil profile by reducing soil compaction. This is of great practical importance for conditions of unstable moisture, since it is the moisture reserves in deeper horizons that can play a significant role in providing plants with water during the growing season of sunflower. The revealed weak nature of the relationship indicates that the amount of precipitation in the autumn-winter period cannot be considered as the only factor determining the development of productive moisture reserves in the soil profile. The largest proportion of changes in moisture reserves associated with precipitation was found for shallow non-mouldboard tillage ($R^2 = 0.1885$), while for mouldboard and deep non-mouldboard tillage, this indicator was even lower – 0.0845 and 0.0377, respectively. The results obtained are consistent with the data by X. Huang *et al*. (2021), who found that the dynamics of soil moisture is determined by the interaction between the moisture regime and changes in the physical properties of the soil under the influence of various cultivation systems. This may indicate that, under different tillage methods, the efficiency with which atmospheric precipitation is converted into productive soil moisture reserves is governed by a combination of factors, including precipitation amount, infiltration conditions, the physical condition of the soil, its water-holding capacity, temperature regime, and moisture losses through evaporation.

## CONCLUSIONS

According to the results of studies conducted in 2022-2026 on typical chernozem of Right-Bank Forest-Steppe of Ukraine, it was established that the method and depth of the primary tillage affected the accumulation and vertical distribution of productive moisture. The highest average supply of productive moisture in 1 metre layer of soil before sowing sunflower was developed by deep non-mouldboard tillage to a depth of 25-27 cm and amounted to 214 mm, which is 10 mm higher than the indicator for deep mouldboard tillage by 25-27 cm (204 mm) and by 23 mm – for shallow non-mouldboard tillage by 14-16 cm (191 mm). The advantage of deep non-mouldboard tillage to a depth of 25-27 cm was most clearly manifested in 40-60 and 80-100 cm layers, where the reserves of productive moisture were 42 and 40 mm, respectively. In a 40-60 cm, this indicator exceeded deep mouldboard and shallow non-mouldboard tillage by 14-16 cm, respectively, by 5 and 11 mm. The results obtained indicate the development of more favourable conditions for the accumulation of moisture in the deeper horizons of the soil profile during deep non-mouldboard tillage. Correlation and regression analysis showed a weak positive relationship between the amount of precipitation in the autumn-winter period and the reserves of productive moisture in a 0-100 cm soil layer for all tillage methods under study. The coefficient of determination was $R^2 = 0.0845$ for deep mouldboard tillage, 0.0377 for deep non-mouldboard tillage at 25-27 cm, and 0.1885 for non-mouldboard processing at 14-16 cm. Furthermore, a limited number of independent annual observations ($n = 5$) reduces the statistical power of correlation and regression analysis, so it is advisable to consider the established dependencies as trends. Deep non-mouldboard tillage to a depth of 25-27 cm was defined as an effective agrotechnical measure for the development of higher reserves of productive moisture in 1 metre layer of typical chernozem before sowing sunflower in the conditions of the Right-Bank Forest-Steppe of Ukraine. The prospects for further research are a comprehensive assessment of the impact of primary tillage methods on the water regime, sunflower yield and productivity, and the agrophysical properties of the soil and the efficiency of using precipitation under various weather conditions.

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# Вплив способів основного обробітку ґрунту на формування запасів продуктивної вологи перед сівбою соняшнику в умовах Правобережного Лісостепу України

**Анотація.** Збереження та ефективне використання продуктивної вологи є одним із визначальних чинників стабільного виробництва соняшнику в умовах нестійкого зволоження та дефіциту атмосферних опадів. Метою дослідження було встановити вплив способу та глибини основного обробітку ґрунту на запаси і вертикальний розподіл продуктивної вологи в чорноземі типовому перед сівбою соняшнику в умовах Правобережного Лісостепу України. Дослідження проводилося у 2022-2026 роках у стаціонарному польовому досліді кафедри землеробства та гербології Національного університету біоресурсів і природокористування України. Досліджувалися полицевий глибокий обробіток на 25-27 см, безполицевий глибокий обробіток на 25-27 см та безполицевий мілкий обробіток на 14-16 см. Запаси продуктивної вологи визначалися у шарі ґрунту 0-100 см за загальноприйнятою методикою. Встановлено, що спосіб та глибина основного обробітку впливали на загальний запас і вертикальний розподіл продуктивної вологи. Найвищий середній запас продуктивної вологи у шарі 0-100 см за роки досліджень сформувався за безполицевого обробітку на 25-27 см і становив 214 мм, тоді як за полицевого обробітку він становив 204 мм, а за безполицевого мілкого обробітку на 14-16 см – 191 мм. Найбільш виражена перевага глибокого безполицевого обробітку спостерігалася у шарах ґрунту 40-60 та 60-100 см. Кореляційно-регресійний аналіз виявив слабкий позитивний зв'язок між сумою атмосферних опадів осінньо-зимового періоду та запасами продуктивної вологи, при цьому коефіцієнт детермінації становив 0,0845 за полицевого глибокого, 0,0377 – безполицевого глибокого та 0,1885 за безполицевого мілкого. Отримані результати обґрунтували доцільність застосування безполицевого глибокого обробітку на 25-27 см для підвищення накопичення та збереження продуктивної вологи у ґрунті перед сівбою соняшнику

**Ключові слова:** чорнозем типовий; глибоке розпушення; осінньо-зимові опади; водний режим ґрунту; дисковий обробіток; оранка