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Formation of sunflower hybrid productivity by resource saving cultivation technologies in southern Ukraine

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Abstract. The implementation of resource-efficient technology in contemporary agricultural production enhances the productivity and efficiency of sunflower farming while mitigating environmental harm. The research aimed to examine the impact of various tillage techniques on sunflower farming in southern Ukraine. A field study was undertaken from 2021 to 2023 at the Educational and Research Centre of Mykolaiv National Agrarian University to achieve this objective. The research established that traditional tillage yields the lowest density of the topsoil (0-10 cm), signifying good soil aeration. At the same time, no-till cultivation is characterised by the highest soil density, but it helps to increase the reserves of productive moisture at all depths. Before sunflower harvesting, the no-till moisture content was 134 mm in the 0-100 cm layer, which is 26 mm more than in conventional

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tillage. The study showed that plant height and vegetative mass growth of sunflowers were higher than no-till in all growth stages. In the phase of two pairs of true leaves, the height of the plants under no-till was 16.8 cm, and during flowering – 176.2 cm. The growth of vegetative mass in the phase of two pairs of true leaves under no-till reached 135 g/m^2 and in the phase of seed formation – 1,380 g/m^2. The leaf area index under no-till was the highest in all phases of sunflower growth, in the flowering phase it was 4.8 m^2/m^2, which is 10% higher than under conventional tillage (4.2). The chlorophyll content was also the highest under no-till and in the flowering phase at 46 (SPAD units). In addition, the sunflower yield under conventional tillage was 3.56 t/ha, under minimum tillage – 3.85 t/ha, and no-till was the highest at 3.95 t/ha. The practical value of the study is to provide scientifically based recommendations for agricultural enterprises on the choice of the optimal method of soil cultivation, which can increase the competitiveness of Ukrainian sunflowers on the world market

Keywords: yield; soil cultivation; agrophysical parameters of soil; plant growth and development; vegetative mass

INTRODUCTION

The sustainable utilisation of natural resources is becoming increasingly critical in the context of population expansion and climate change. Population growth puts additional pressure on agriculture, increasing demand for food, fodder crops and raw materials for industry. At the same time, climate change is leading to a decrease in the availability of water resources, soil degradation and an increase in the frequency of extreme weather events such as droughts, floods and hurricanes. This makes it more difficult to ensure stable yields and increases risks for the agricultural sector (Coêlho *et al.*, 2022).

The rational use of natural resources such as water, soil, energy and fertilisers are becoming a key factor in ensuring the sustainable development of agriculture. Adapting agriculture to climate change requires a comprehensive approach. M. Duca *et al*. (2022) assert that employing hybrids resistant to adverse environments might markedly enhance plant resilience to extreme weather events. Agricultural practices, such as improving soil structure and its ability to retain moisture, can reduce the negative impact of climate change on crop yields. Risk management strategies development can assist in coping with unpredictable climate change and ensure the resilience of agricultural systems. Such strategies include developing plans for droughts or other abnormal weather events, as well as applying new technologies and farming methods.

The development of precision agriculture, including the use of drones and sensor technologies, contributes to more efficient resource management and cost reduction. Research in the field of agronomy and ecology allows for the development of new ways of cultivating soil, fertilising and managing water resources, which contributes to the resilience of agricultural systems (Casali *et al.*, 2022). According to S.I. Haruna & N.V. Nkongolo (2019) and B. Basile *et al*. (2021), resource-saving technologies can improve farm efficiency. In sunflower production, these technologies may encompass new hybrids distinguished by elevated yields, resilience to adverse environments, illnesses, and pests, as well as the efficient utilisation of available resources.

Sunflower is one of the most popular oilseeds in Ukraine, used to meet domestic needs and in exporting products. S. Kalenska *et al*. (2020) underscore the necessity of implementing resource-efficient growing practices in contemporary agricultural production, which enhance sunflower yield while mitigating environmental detriment. Among these technologies is no-till cultivation, which helps to preserve its structure and improve water retention properties. I. Kolosok (2022) believes that the use of no-till not only reduces the time and resources spent on tillage but also helps preserve moisture in the soil, which is especially important in arid climates. Precision agriculture systems, which use GPS navigation, drones, sensors and analytical software to collect and analyse data on soil, plant and weather conditions, can help determine exactly where and when to apply fertiliser or water to maximise resource efficiency and reduce costs. Following O. Kovalenko *et al*. (2024), mulching is also an effective element of cultivation technology, which involves covering the soil surface with organic or inorganic materials. Mulching not only helps to retain moisture, which is critical to ensuring crop stability but also reduces erosion, which helps to maintain soil fertility.

The implementation of resource-efficient technology improves the efficacy of sunflower cultivation and markedly diminishes the ecological footprint of agricultural output, which is crucial for the sector's sustainable development through resource conservation and the promotion of enduring productivity. Nevertheless, current research predominantly emphasises general energy-saving principles and inadequately considers their adaptation to particular regional conditions, such as the hot, low-humidity summers of southern Ukraine, which significantly impact sunflower cultivation and

necessitate comprehensive energy-efficient solutions. The present research aimed to examine the impact of different tillage technologies on sunflower agriculture by evaluating the effects of various soil cultivation methods on agrophysical parameters, the growth and development of sunflower plants, and overall crop yield.

MATERIALS AND METHODS

From 2021 to 2023, a field experiment was carried out at the Educational and Research Centre of Mykolaiv National Agrarian University to investigate resource-efficient sunflower growing techniques with the P64HE133 hybrid. The studies were conducted on southern chernozem soil characterised by a neutral pH (6.8-7.2), elevated humus content (123-125 g/kg), and sufficient concentrations of nitrates, phosphate, and potassium. Sunflowers were planted at a density of 50,000 seeds per hectare while soil temperatures ranged from 8 to 10°C, succeeding winter wheat as the preceding crop. The 320 m^2 study area, comprising a 90 m^2 survey plot, was replicated thrice and evaluated three soil cultivation techniques: traditional ploughing to 25 cm followed by harrowing and shallow cultivation to 5-10 cm, minimal tillage employing disc harrows to a depth of 10-15 cm, and no-till, which preserves plant residues on the surface to mitigate erosion and enhance moisture retention. Laboratory and field observations were employed to evaluate plant growth, development, and yield under various growing strategies.

The research assessed the agrophysical properties of the soil, specifically the density of the topsoil, employing the M.A. Kachinsky method (Feketa, 2015), at intervals of 10 cm to a depth of 30 cm, and evaluated soil moisture using the thermostat-weight technique, measuring moisture content at various depths every 10 cm up to 100 cm through drying at 105°C. To evaluate the impact of different tillage methods on the growth and development of sunflower plants, regular measurements of plant height and vegetative mass growth were made in the following phases of sunflower growth and development: two pairs of true leaves, budding, flowering and seed formation. A metric ruler was used to measure the height of the plants, starting from the base of the stem to the top of the plant. This method was used to accurately track changes in plant height over time. To determine the vegetative mass, plant samples were collected, weighed the fresh weight and calculated for the average value for each variant.

Two key metrics were used to assess the photosynthetic activity of sunflowers under the influence of different tillage methods: leaf surface index and photosynthetic potential. To measure the leaf surface index, a portable leaf index analyser LI-COR LAI-2200C (LI-COR Biosciences, USA) was used. A portable device SPAD-Plus (Konica Minolta, Japan) was used to determine the photosynthetic potential. Harvest accounting was conducted with the continuous harvesting method on the designated plot, then converting the results to hectares. The data underwent processing via the multivariate analysis of variance (MANOVA) method, executed using Microsoft Excel and Statistica 10. The results were deemed statistically significant if the probability value (P) was less than or equal to 0.05, as assessed by the Student's T-test. The study was conducted following the requirements of the Convention "On Biological Diversity" (1992), as well as safety conditions.

RESULTS

Soil cultivation techniques profoundly impact soil structure, hydrology, and aeration, thus influencing plant growth and development. The study revealed that standard, minimal, and no-till methods differentially affected soil density at various depths (Fig. 1). Conventional tillage resulted in the lowest density of 1.1 g/cm^3 in the upper 0-10 cm layer, signifying effective loosening and enhanced soil structure, whereas density increased to 1.25 g/cm^3 at 20-30 cm due to diminished tillage practices. Minimal tillage led to a marginally elevated top-layer density of 1.13 g/cm^3, which increased to 1.33 g/cm^3 in deeper layers, indicating reduced soil aeration. No-till methods demonstrated the highest densities, recording 1.21 g/cm^3 in the surface layer and rising to 1.36 g/cm^3 at a depth of 20-30 cm, attributed to the accumulation of organic residues and the absence of mechanical disturbance. These variances illustrate the impact of diverse tillage practices on the agrophysical properties of soil, hence affecting total agricultural production.

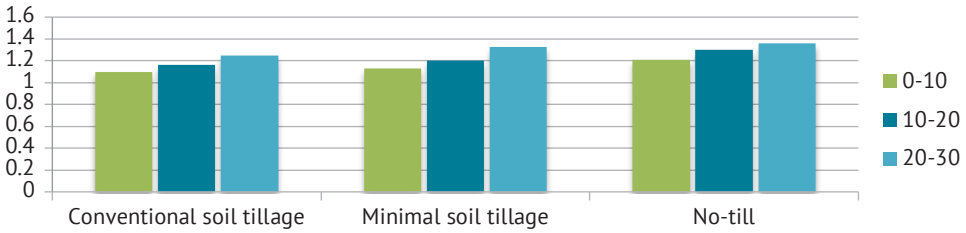

Figure 1. *Impact of ploughing techniques on soil density prior to sunflower harvest, g/cm^3 (average for 2021-2023)*
Source: *compiled by the authors*

Soil moisture reserves are essential for the growth and development of crops, such as sunflowers. Soil moisture is influenced by numerous ways, with soil cultivation practices being particularly significant. The no-till approach has demonstrated superior efficacy in retaining soil moisture, hence enhancing plant growth, particularly under conditions of inadequate moisture. Consequently, the soil moisture before to harvesting sunflowers employing no-till in the 0-100 cm layer was 135 mm, exceeding minimum tillage by 9 mm and conventional tillage by 25 mm (Fig. 2).

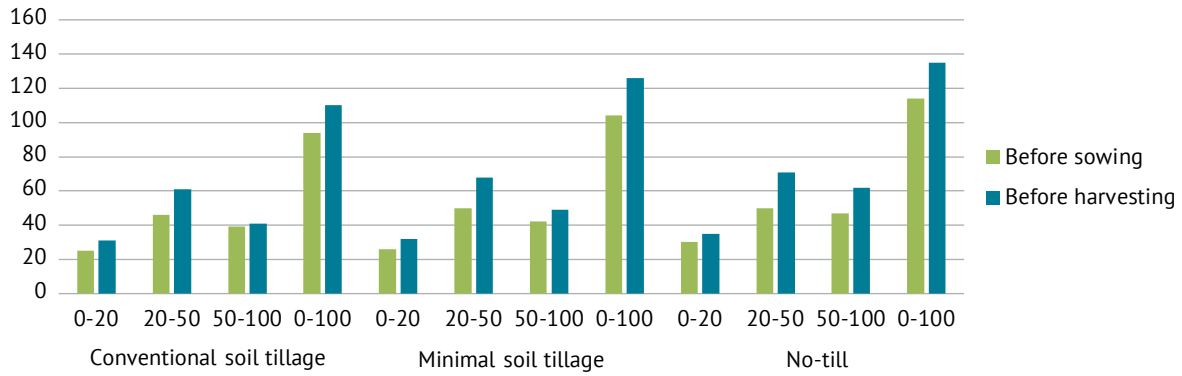

Figure 2. *Productive soil moisture reserves depending on cultivation methods, mm (average for 2021-2023)*
Source: *compiled by the authors*

The height of plants is an important metric of their growth and development, which affects the yield and general condition of crops. In this context, analysing the height of sunflower plants at different stages of their development is critical for assessing the effectiveness of different tillage methods. Table 1 shows the results of sunflower plant height measurements for three different tillage methods: traditional, minimal and no-till.

Table 1. *Growth in height of sunflower hybrid plants, depending on soil cultivation methods, cm (average for 2021-2023)*

Growth and development phase	Conventional soil tillage	Minimal soil tillage	No-till
Two pairs of real leaves	15.2	15.5	16.8
Budding	55.4	56.1	58.7
Blooming	170.8	172.3	176.2

Source: *compiled by the authors*

The height of the sunflower in the phase of two pairs of true leaves was the lowest for all treatments, but no-till provided the highest (16.8 cm) compared to the traditional (15.2 cm) and the lowest (15.5 cm). This shows the potential of no-till to improve early plant development. In the budding phase, the height of the plants under no-till reached 58.7 cm, which is the highest among the three methods. This is a sign of better plant development, which is supported by the optimal conditions provided by no-till. Plant height at flowering was also the highest for no-till (176.2 cm), confirming that no-till not only supports early development but also promotes plant growth in later stages. This demonstrates the positive impact of no-till on plant growth and a possible increase in yields.

Vegetative mass growth is a critical metric for assessing the effectiveness of agronomic practices, as it reflects plant development, health and productivity potential. The results of measurements of vegetative mass growth of sunflower plants under three different tillage methods show that in the phase of two pairs of true leaves, the mass growth was the lowest for all tillage options, but no-till provided the highest rate – 135 g/m^2 compared to traditional (120 g/m^2) and minimum (125 g/m^2) tillage. This shows the advantage of no-till in ensuring better plant development. In the budding and flowering phases of sunflower, the growth of vegetative mass under no-till reached 445 and 1,005 g/m^2, respectively, indicating that no-till contributes to a more efficient accumulation of vegetative mass in the middle stage of plant development. In the phase of seed formation, the growth of vegetative mass under no-till reached 1,380 g/m^2, which is 80 and 55 g/m^2 higher than under conventional and minimum tillage, respectively (Table 2).

Table 2. *Growth of vegetative mass of sunflower hybrid, depending on soil cultivation methods, g/m2 (average for 2021-2023)*

Growth and development phase	Conventional soil tillage	Minimal soil tillage	No-till
Two pairs of real leaves	120	125	135
Budding	400	420	445
Blooming	950	970	1,005
Seed formation	1,300	1,325	1,380

Source: *compiled by the authors*

Thus, in the phase of two pairs of true leaves, no-till influenced the formation of the leaf surface index at the level of 0.4 m^2/m^2, which was higher than in conventional tillage (0.3 m^2/m^2) and minimal tillage (0.35 m^2/m^2). During budding, the no-till leaf surface index was 3.5, while in conventional tillage it was 3 and while minimum tillage – 3.3. During the flowering phase of no-till, the leaf surface index was 4.8, which was higher than conventional tillage (4.3) and minimum tillage (4.5). In general, the data show that no-till has a positive effect on the growth of the sunflower hybrid, providing the highest leaf area indexes at all growth stages. This shows that reducing soil disturbance through no-till can lead to improved crop growth and productivity (Fig. 3). Thus, no-till is the most effective for increasing the leaf area index in all phases of sunflower growth. But it is worth noting that minimal tillage also shows a positive impact on plant development compared to conventional tillage.

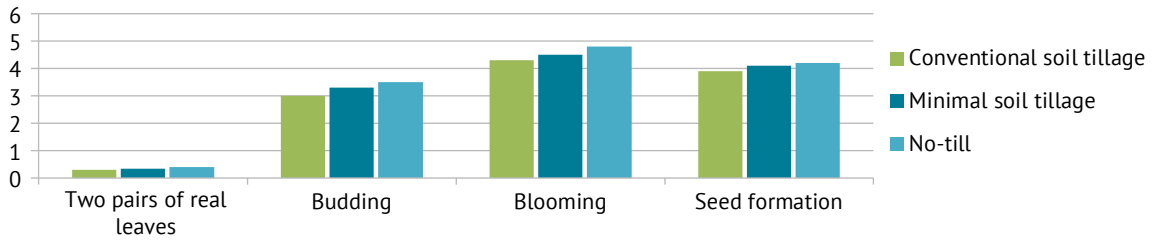

Figure 3. *Leaf area index of sunflower hybrid depending on soil cultivation methods, m^2/m^2 (average for 2021-2023)*
Source: *compiled by the authors*

The chlorophyll content, assessed by the SPAD index as a measure of photosynthetic efficiency, was utilised to examine the impact of various soil cultivation methods on photosynthetic processes and overall plant health during critical growth stages. The research indicated that in the budding phase, no-till farming produced the greatest chlorophyll content, surpassing conventional tillage by 4.7 and minimal tillage by 3.4%. Minimal tillage exhibited a 1.3% increase in chlorophyll content relative to conventional tillage, signifying a moderate improvement in photosynthetic activity and plant health under reduced soil disturbance procedures. Using no-till, the chlorophyll content in the flowering phase of sunflower was the highest, exceeding conventional cultivation by 4.0 and minimum tillage by 2.8%. However, at the stage of sunflower seed formation, photosynthetic activity decreased (Fig. 4).

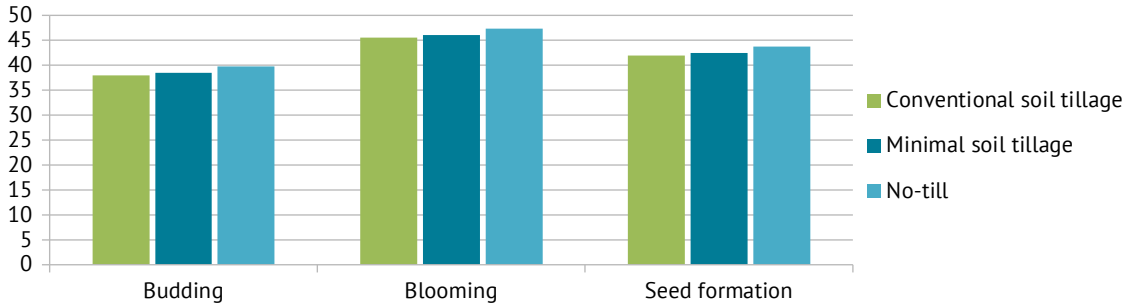

Figure 4. *Chlorophyll content in the leaves of sunflower hybrid depending on soil cultivation methods, SPAD units (average for 2021-2023)*
Source: *compiled by the authors*

The study findings demonstrate that no-till cultivation is the most effective method for enhancing sunflower photosynthetic activity across all growth phases, as indicated by the highest SPAD index compared to minimal and traditional tillage. Minimal tillage also positively affects photosynthetic efficiency, though to a lesser extent, while traditional tillage results in the lowest SPAD index. Additionally, the tillage method significantly impacts sunflower yields, with conventional tillage averaging 3.56 t/ha, minimal tillage achieving 3.85 t/ha, and no-till producing the highest average yield of 3.95 t/ha from 2021 to 2023. These findings highlight the superior performance of no-till practices in both plant health and crop productivity.

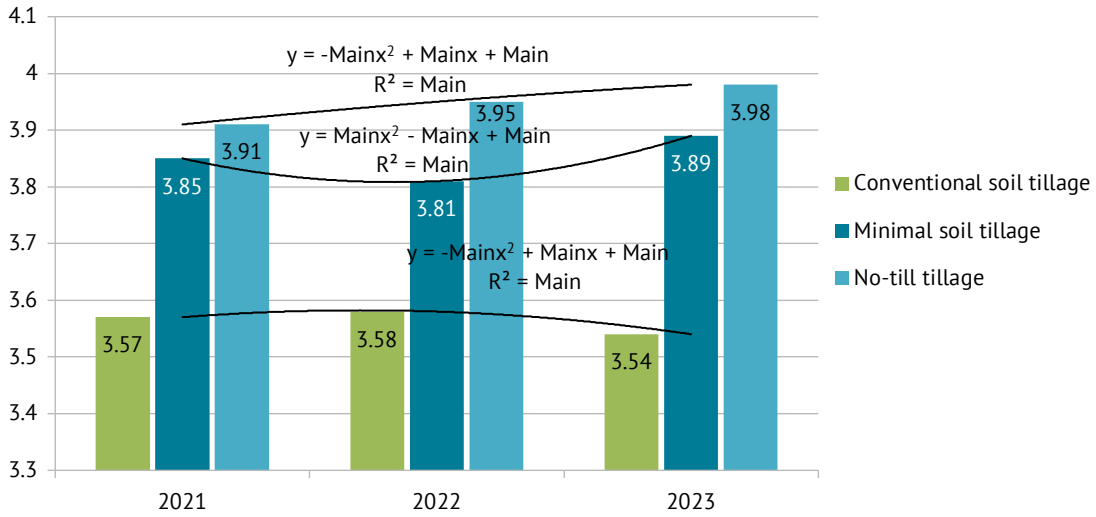

Figure 5. *Sunflower hybrid seed yield depending on cultivation methods, t/ha*
Source: *compiled by the authors*

In general, the results of the study show that no-till is the most effective way to improve the growth and development of sunflowers, including plant height, vegetative mass growth, leaf area index and photosynthetic potential. This method provides optimum conditions for plant development, preserves productive soil moisture and increases sunflower yields, making it recommended for use in southern Ukraine as a resource-saving sunflower cultivation technology.

DISCUSSION

Awareness of the necessity for sustainable production has increased, necessitating ongoing enhancement of agronomic techniques. The amalgamation of scientific inquiry, cutting-edge technologies, and effective resource management is increasingly vital to this process (Howell *et al.*, 2015). Most authors, including D.D. Avgoustaki & G. Xydis (2020) and O. Sydiakina & M. Ivaniv (2023), agree that the formation of sunflower hybrids productivity with the use of resource-saving technologies is a critical aspect of modern agricultural production. These technologies help to increase the productivity of sunflower hybrids by improving the conditions for their growth and development. They ensure optimum soil moisture and nutrient levels, which are critical to achieving high yields.

In addition, the results of numerous studies by scientists confirm that the use of resource-saving technologies leads to an increase in yields and product quality (Perea-Moreno *et al.*, 2018). According to V. Radić *et al.* (2021), the introduction of such technologies not only improves the physical and chemical properties of the soil but also contributes to an increase in microbiological activity, which in turn improves the availability of nutrients for plants. Importantly, this approach helps to preserve soil moisture, which is a critical factor in a changing climate, increasing the resistance of sunflower hybrids to drought and other stressful conditions.

The use of resource-saving technologies in agricultural production can lead to a significant reduction in energy costs, such as fuel for tillage, and reduce the need for chemical fertilisers. This can be achieved by optimising tillage processes, using energy-efficient equipment and precision farming. The findings of B. Li *et al.* (2022) affirm that optimising energy and material resource costs positively influences the economic efficiency of agricultural production, resulting in enhanced profits for agricultural producers and greater market competitiveness. In addition, reducing the cost of resource-saving technologies leads to a reduction in the overall environmental burden, as it reduces greenhouse gas emissions, and soil and water pollution, and

helps to preserve biodiversity and ecosystem services. Thus, the use of resource-saving technologies in agricultural production can be beneficial not only for agricultural producers but also for the environment (Nardón *et al.*, 2021).

It should be noted that resource-saving technologies help improve soil quality by reducing erosion, preserving organic matter and improving its structure. As confirmed by Ya. Tsymbal *et al.* (2022), the use of mulching and no-till helps to preserve moisture, improve aeration and reduce the need for additional erosion control measures, which was also confirmed in the present study. This creates optimal conditions for plant growth, which in turn increases their productivity. According to the results of V. Gamayunova & A. Panfilova (2020), resource-saving technologies reduce the incidence of plant diseases by 30 and pests by 25% compared to traditional cultivation methods. This highlights the effectiveness of conservation practices in increasing overall plant resilience, which is associated with improved moisture retention, improved soil structure and optimised conditions for crop growth and development. Researchers such as A. Ozturk *et al.* (2022) and A.U. Jan *et al.* (2022), emphasise the need to optimise tillage technologies, especially in the southern regions. In these areas, where drought management and effective soil moisture conservation are critical, the right choice of cultivation methods can significantly improve crop production.

The results obtained show that no-till promotes plant height growth and increases vegetative mass. O. Tsyliuryk *et al.* (2021) also emphasise that no-till improves root development and promotes more efficient use of water and nutrients, which in turn leads to an increase in total biomass. However, I. Demir (2020) noted that in certain conditions, no-till can lead to a slowdown in initial plant growth. This is due to the limited access to certain nutrients that conventional tillage usually provides. Thus, although no-till demonstrates advantages in the long run, it is necessary to account for possible initial difficulties and adjust technological approaches to the specific conditions and needs of agricultural production.

The results of this study are consistent with the findings of V. Giannini *et al.* (2022), who noted that no-till improves its structure and aeration, which contributes to a more even distribution of the plant root system. This, in turn, increases their ability to absorb nutrients and moisture, which is a key factor in increasing photosynthetic activity. The authors also noted that reduction of mechanical impact on the soil with no-till reduces stress on plants, which contributes to better growth and increased yields. As such, despite the numerous benefits of resource-saving technologies, certain challenges should be considered. Following R. Puttha *et al.* (2023), even though no-till and other resource-saving methods can significantly improve soil quality and reduce resource costs, their implementation can be fraught with difficulties. These technologies require careful management of crop residues, which can accumulate on the soil surface and can lead to problems with disease and pest control, which contributes to their spread, and require additional measures to maintain plant health. In addition, the introduction of resource-saving technologies often involves the use of specialised equipment and technologies that may not be economically feasible for small farms or those who are just beginning to adapt to new methods. The cost of such equipment and the need for additional knowledge and skills to use it effectively can be a barrier for some agricultural producers (Domaratskiy *et al.*, 2023).

Thus, based on scientific research and analysis, the implementation of energy-efficient technology in sunflower production is a fundamental component of sustainable agricultural development. These technologies facilitate the conservation of natural resources, mitigate environmental degradation, and enhance the economic efficiency of agricultural output. The successful adoption of resource-saving technologies necessitates a holistic approach, encompassing meticulous planning and financial backing to guarantee the establishment of all requisite circumstances for their optimal utilisation.

CONCLUSIONS

The study demonstrated that soil cultivation methods significantly affect its density and water management, as well as the development and growth of sunflower plants. Conventional tillage resulted in the lowest density in the upper layer (0-10 cm), at 1.1 g/cm^3, signifying effective aeration and enhanced soil structure in this stratum. No-till had the greatest soil density, specifically 1.21 g/cm^3 in the 0-10 cm soil layer, and at a depth of 20-30 cm, the density attained 1.36 g/cm^3. A reduction in tillage intensity resulted in an augmentation of productive moisture stores at all depths. Prior to sunflower harvesting utilising no-till methods, the soil moisture within the 0-100 cm layer measured 135 mm, above that of traditional tillage by 25 mm (110 mm).

The examination of sunflower plant height indicates that at the stage of two pairs of true leaves, the height of plants under no-till was 16.8 cm, surpassing that of traditional tillage (15.2 cm) and minimum tillage (15.5 cm). During the flowering of sunflowers, the height of the plants under no-till was 176.2 cm. The growth of the vegetative mass of sunflower in the phase of two pairs of true leaves under no-till was 135 g/m^2, which is

higher than under traditional (120 g/m^2) and minimum (125 g/m^2) treatments. In the phase of seed formation, the growth of vegetative mass under no-till reached 1,380 g/m^2, which exceeded the metrics of traditional (1,300 g/m^2) and minimum (1,325 g/m^2) treatments.

The study determined that no-till is the most effective for increasing the leaf surface index and chlorophyll content in sunflower leaves at all stages of their development. No-till provides the highest leaf area index (0.4-4.8) and chlorophyll content (34.5-47.3) compared to conventional (0.3-4.3 and 32.5-45.5 respectively) and minimum tillage (0.35-4.5 and 33-46 respectively). Minimal tillage also shows a positive effect on plant development compared to conventional tillage, although to a lesser extent than no till. The limitations of the study were determined by only one climate region, which may limit the generalisability of the results. Further research should address the effectiveness of no-till in different climatic zones to determine its efficiency.

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None.

CONFLICT OF INTEREST

None.

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Формування продуктивності гібридів соняшнику за ресурсозберігаючими технологіями вирощування в умовах півдня України

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Анотація. Впровадження ресурсоефективних технологій у сучасному сільськогосподарському виробництві підвищує продуктивність та ефективність вирощування соняшнику, одночасно зменшуючи шкоду для навколишнього середовища. Метою дослідження було вивчення впливу різних способів обробітку ґрунту на вирощування соняшнику на півдні України. Для досягнення цієї мети з 2021 по 2023 рік було проведено польове дослідження в Навчально-науковому центрі Миколаївського національного аграрного університету. Дослідження показало, що традиційний обробіток ґрунту забезпечує найнижчу щільність верхнього шару ґрунту (0-10 см), що свідчить про добру аерацію ґрунту. Водночас, безвідвальний обробіток (no-till) характеризується найбільшою щільністю ґрунту, але сприяє збільшенню запасів продуктивної вологи на всіх глибинах. Зокрема, перед збиранням соняшнику no-till вологість становила 134 мм у шарі 0-100 см, що на 26 мм більше порівняно з традиційним обробітком. Дослідження продемонструвало, що висота рослин та наростання вегетативної маси соняшнику були вищими за no-till у всіх фазах росту. У фазі двох пар справжніх листків висота рослин при no-till становила 16,8 см, а під час цвітіння – 176,2 см. Наростання вегетативної маси у фазі двох пар справжніх листків за no-till досягало 135 г/м^2, а у фазі утворення насіння – 1380 г/м^2. Індекс листкової поверхні за no-till був найвищим у всіх фазах росту соняшнику, зокрема у фазі цвітіння він становив 4,8 м^2/м^2, що на 10 % більше порівняно з традиційним обробітком (4,2). Вміст хлорофілу також був найвищим за no-till, і у фазі цвітіння становив 46 (одиниці SPAD). Крім того, врожайність соняшнику за традиційного обробітку ґрунту становила 3,56 т/га, за мінімального – 3,85 т/га, а за no-till була найвищою, і сягала 3,95 т/га. Практична цінність дослідження полягає у наданні науково обґрунтованих рекомендацій для сільськогосподарських підприємств щодо вибору оптимального способу обробітку ґрунту, що може збільшити конкурентоспроможність українського соняшнику на світовому ринку

Ключові слова: врожайність; обробіток ґрунту; агрофізичні показники ґрунту; ріст і розвиток рослин; вегетативна маса