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ECONOMIC EFFICIENCY OF CORN GRAIN CULTIVATION WITH THE NEW TECHNOLOGIES OF TILLAGE AND IRRIGATION

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Abstract

In the context of climate change, there is a growing need to study the impact of environmental factors on plant life. This, in turn, will allow the reasonable use of agricultural techniques, to form high-yielding crops, and increase crop productivity. The following variants of tillage and irrigation technologies were included in the research scheme (i) conventional tillage without irrigation; (ii) no-till without irrigation; (iii) no-till with drip irrigation system; (iv) no-till with system of subsoil drip irrigation. Corn yield varied significantly from the studied factors of cultivation technology. The highest productivity of 12.1 t/ha was obtained under no-till with a system of subsurface drip irrigation and 12.0 t/ha under no-till with drip irrigation system. During the statistical processing of the obtained experimental data, no significant difference between the studied variants was found. Carrying out an economic analysis of corn growing in the arid climate of the Southern Steppe of Ukraine testifies to the high efficiency of application of the new tillage and irrigation systems in the cultivation technology. The application of no-till with drip irrigation system allowed to obtain grain with a cost of 3.72 UAH/t, to obtain a profit of 50.13 UAH/ha with a level of production profitability of 112.2%. It should be noted that the use of no-till with system of subsoil drip irrigation led to slightly lower indicators of economic efficiency of corn cultivation, under which the level of production profitability was 109.0%.

Key words**:** *corn, soil tillage, subsurface drip irrigation, economy, efficiency*

INTRODUCTION

Today, the most important task that society must constantly solve is to increase the production of food and various raw materials by intensifying the agricultural sector, which includes improving the existing and justifying the new, modern structure of sown areas, taking into account market conditions and raw materials; improving tillage technologies, minimizing or moving to no-till; optimization fertilizer system and plants protection from pests; introduction of a set of reclamation and soil protection measures; introduction of new technologies for growing crops, taking into account advances in genetics, breeding, biotechnology.
In the context of climate change, there is a growing need to study the impact of environmental factors on plant life. This, in turn, will allow the proper application of agricultural techniques, the formation of high-yield crops, increased the productivity of both crop production, and, if possible, the restoration of livestock. In recent years, climatic conditions have changed dramatically, so it is impossible to grow crops under a single scheme. This requires a differentiated approach, taking into account all weather conditions. The main component of crop production technologies is the choice of a tillage system, so inefficient tillage can lead to the disruption of plant life factors that affect soil fertility.
Currently, the level of the plowed area in Ukraine is one of the largest in the world and consists of 53.9%, while in Poland it is 36.5%, Germany is 34.1%, the United States

is 17.5%, China is 12.0%. According to FAO estimates, 20% of agricultural land in Ukraine has already undergone significant degradation, and the rest is under threat. Over the last 130 years, Ukrainian soils have lost almost 30% of their organic matter (humus). According to the National Academy of Agrarian Sciences of Ukraine estimates, the economic damage from soil degradation is about 40 billion UAH/year [19, 43].

Traditional management practice shows results when the harvest is almost 80% dependent on nature, in turn, no-till can reduce to 20% the impact of weather and climate [3, 19, 43]. In general, in conventional tillage, six groups of microbiological cenoses are present in the soil, and when plowing is abandoned after 3–5 years, three more groups are gradually added, which corresponds to microbiological cenoses of virgin soils [35]. Thus, it gets a biologically active soil that can decompose, process, and redistribute all the organic matter that remains in it. It was also found that five minutes after cultivation in the layer of 0-10 cm is three times less carbon dioxide than before cultivation [20].

Currently, for European countries, the selection of tillage technologies is a very important issue. Impressive results and the rapid introduction of no-till in North and Latin America, and Southeast Asia are not an example for European countries, so the spread of these technologies is slow. Based on long-term unparalleled field trials in Latin America in the United Kingdom, Germany, Norway, Denmark, Estonia, France, and other countries, the benefits of these technologies have been established, but no large-scale implementation has been reported [28].

To choose a tillage system, it is necessary to take into account natural and climatic conditions, soil diversity in the fields of the economy, and the financial capabilities of the owner to introduce new technologies. Restrictions on the use of soil herbicides to control weeds in strip-till and no-till systems involve the application of active ingredients of continuous action before sowing, or after sowing to the seedlings of the main crop. Increased levels of chemical and biological control of diseases and pests in these systems are offset by high yields due to preserved moisture in the upper soil layers, especially in the dry Steppe zone in Ukraine.

In modern agriculture, there are several basic tillage systems as conventional with moldboard, minimum tillage (mini-till), tape (strip-till), without plowing (no-till) [2, 4, 5, 10, 24, 27, 31].

Conventional tillage provides for shelf plowing with a turn of the layer, which creates a clean arable surface, plant remains are wrapped to a depth of 20-30 cm. The advantages of the technology are creating comfortable conditions for pre-sowing cultivation for friendly seed germination; ensuring optimal impregnation of moisture along to the soil profile and the distribution of minerals in the arable layer; relatively low pressure on the ground by mechanical units; possibility of applying high rates of organic and mineral fertilizers; optimization of chemical plant protection. The disadvantages of the technology are the creation of a dense plow sole, which prevents penetration into the lower layers of water and complicates the development of the root system in depth. This technology is not recommended for soils prone to drying, wind, and water erosion. Periodic deep loosening, once every 3-4 years is mandatory.

No-till is a modern system of agriculture, which does not carry out plowing, herewith the land surface is covered with a layer of especially crushed plant residues (mulch). No-till is the sowing of the crops in previously untreated soil, by opening a narrow opening, a strip only for sufficient width and depth for proper placement of seeds, with no other preparation [33]. The advantages of the technology are a minimal number of passes of heavy units in the field, lower energy and financial costs per unit area during cultivation; under the layer of plant remains, winter moisture is stored for a long time and there is limited evaporation during droughts; prevents all types of soil erosion and excessive overheating of the top layer during periods of high temperatures. The disadvantages of the technology are restrictions on the control of harmful vegetation without mechanical intervention, increased risk of fungal diseases (especially saprophytic fungi) and pests that overwinter in plant remains; limited early sowing in the spring, as the heating and drying of the topsoil is slow due to the presence of a layer of plant residues, so the optimal sowing time is very short; application of high rates of mineral fertilizers is limited and it is necessary to use additional special equipment; the content of phosphorus, potassium, and acidity must be equalized before the introduction of technology; requires the use of special sowing equipment with high opener pressure on the soil, which involves additional financial costs. The use of vertical tillage (deep loosening) is necessary for 5-6 years, as there is significant compaction on the tracks of heavy machinery. In arid steppe areas, dry plant residues on the soil surface can be a material for fire both before and after sowing [37, 42]. It represents a modern model of tillage, according to which it is not affected by traditional mechanical impact, but leaves crushed plant remains, covering the surface and forming mulch [32, 34, 43]. The "zero" method of agriculture (no-till) should not be taken lightly, only as a refusal to plow, because this method is primarily a complex technological model that requires special knowledge and the availability of highly qualified specialists and special equipment, so the positive effect of its application can be obtained only using integrated and systematic approaches [9, 13, 18]. Thus, in the United States, where this technology is currently used on 25% of arable land, in 16 years there has been an increase in organic matter from 2.0 to 3.5% [14]. The farmer Non Pereira in Brazil switched to use of no-till 30 years ago when the amount of organic matter in the soil was 1%, and today it's close to 4%. During this time, corn yield increased from 4.0 to 8.0 t/ha, and the number of fertilizers applied decreased from 400 to 260 kg/ha while the price of land was twice as high as with conventional technologies [3, 39]. According to foreign researchers, the effect of inhibiting seed germination begins with the number of crop residues of 3,000 kg/ha and increases to about 12% for every additional 1,000 kg/ha of residues [16, 20, 36]. Although the soil is not cultivated with constant use of no-till, special tillage is often required to switch to this system [30]. The main requirement for the field, when using no-till, is a flat soil surface [15, 25], only, in this case, can special drills work properly, otherwise, they will sow some seeds too deep or, conversely, too shallow, which will affect yields [23, 30]. Unlike traditional farming, stubble is not burned or plowed into the ground, straw is not removed from the fields. Non-commodity residues, such as straw, are crushed to a certain size after harvest and then evenly distributed over the field [16, 26]. The surface forms a soil-protective coating, a mixture of soil and crushed crop residues, which resists water and wind erosion, preserves moisture, prevents weed growth, enhances soil microflora, and is the basis for the reproduction of the fertile soil layer and further increases yields [8, 17]. Proper management of the system of no-till requires as much mulch [1, 7, 16]. Accordingly, when growing crops take into account not only the yield of the commodity part but also the cultivation of maximum biomass, for example, it is desirable to grow tall rather than low wheat varieties, to introduce crop rotation with a large amount of biomass such as corn, etc. Also, sowing for no-till requires special drills that are significantly wider than conventional ones [38], which significantly saves fuel, and working time for people and machines.

According to research, prices for fuel, machinery, fertilizers, and pesticides are rising every year or even quarterly, and agricultural products are growing very slowly. Therefore, to ensure stability, the necessary system of agriculture and technology will ensure a high level of profitability of crop production, while not leading to soil degradation and allowing future generations to leave a fairly fertile soil. According to many farmers and scientists, this technology is no-till, in which crop production is manageable, predictable, and cost-effective [1, 12, 39].

In 2003, at the Second World Congress, three basic no-till principles were formulated which are still actual as the minimal mechanical impact on the soil, permanent vegetation, and maximally adapted crop rotations. Adherence to these principles allows, on the one hand, to preserve and increase the fertility and microbiological activity of the soil, improve its structure, ensure maximum preservation and increase the level of soil moisture, and reduce energy consumption. On the other hand, there is an opportunity to reduce investment, as well as the cost of fuel and lubricants, repairs, and reduce working hours [11, 41].

In this context, the purpose of the paper is to comparatively analyze the impact of climate change on corn crop economic efficiency in an experiment including four variants of tillage and irrigation technologies: (i) conventional tillage without irrigation; (ii) no-till without irrigation; (iii) no-till with drip irrigation; (iv) no-till with subsurface drip irrigation in 2021 at the State Enterprise “Research Farm “Velyki Klyny” of the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine.

MATERIALS AND METHODS

The research farm “Velyki Klyny” of the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine is located in the Black Sea lowland of the Left Bank of the Dnipro within the second floodplain terrace, and a plain with a total slope from north to south and administratively belongs to the Velykyi Klyn village of Kherson region, Ukraine (46°19'48"N lat. 32°36'05"E long.).

The general microclimate of the territory is semi-desert, but temperate, with signs of subtropical continental. In summer, the sand of the adjacent desert heats up to + 70ºC, and hot rising streams from the sands disperse rain clouds. During the growing season the total amount of productive precipitation on the farm rarely exceeds 200 mm, and the hydrothermal coefficient is 0.40-0.45. The extreme natural phenomena also should be noted frequent dry spells, which in some years last up to 60 days, and dust storms lasting up to 20 days a year. The average annual air temperature is + 9.9ºC, and the sum of effective temperatures is 3,300-3,400ºC. The average duration of the growing season is 225-230 days.

Precipitation during the year falls unevenly. The amount of precipitation that falls during the growing season is not enough to compensate for the amount of total evaporation during the growing of crops. To reduce the impact of adverse climatic factors and replenish moisture, the soil needs irrigation [6, 21, 22]. One of the most important meteorological indicators for agricultural science is the amount of precipitation during the growing season of the studied crop. Effective precipitation is one of the components in the future calculation of total water consumption and unit formation. It is important to consider not only their number, but also the distribution of time, intensity, efficiency, and so on.

The research compared the data obtained from Internet meteorological stations on precipitation and temperature, with long-term averages for the May-September period (Table 1).

During the growing season, in 2021 there were 227.1 mm of precipitation, which is 29.1 mm more than the long-term average for this period and their distribution over the growing season was uneven. The 45% of precipitation fell in the first decade of July with an amount of 102.9 mm, which is 87.9% more than the long-term average; 22% in the second decade of June; 13% in the first decade of August. In other periods of vegetation, precipitation was almost not observed. Summer was hot with rainfall, which was torrential in nature and fell unevenly in intensity. June was hot with precipitation in the second and third decades (in general amount was 61.1 mm).

The average monthly air temperature is 22.8ºC, which is 2.5ºC above the norm. Heavy rains with strong winds were observed in July. The average air temperature for the period of May to September was 21.5ºC, which is higher than the norm by 2.0ºC. The maximum air temperature rose to 35°C (on June 23), which was the absolute maximum temperature for the entire observation period (Table 1).

Table 1. Average long-term and actual values of climatic indicators

Indicators	Months															Sum of precipi-tation
	May			June			July			August			September			
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Temperature of air, ºC																
Long-term	15.8	15.8	15.8	20.3	20.3	20.3	23.0	23.0	23.0	22.2	22.2	22.2	16.5	16.5	16.5	19.6
2021	18.2	18.7	15.6	20.6	23.2	24.8	26.1	22.8	23.9	24.2	21.7	23.4	22.9	19.7	17.4	21.5
Relative humidity, %																
Long-term	67.0	67.0	67.0	64.0	64.0	64.0	59.0	59.0	59.0	59.0	59.0	59.0	66.0	66.0	66.0	63.0
2021	72.7	70.9	77.5	62.6	68.1	59.4	50.6	52.4	62.1	49.8	55.7	50.6	54.0	45.0	52.5	58.9
Precipitation, mm																
Long-term	13.0	13.0	13.0	17.0	17.0	17.0	15.0	15.0	15.0	11.0	11.0	11.0	10.0	10.0	10.0	198.0
2021	0.0	0.0	0.0	0.0	49.4	11.7	102.9	6.0	0.0	29.0	6.4	0.0	0.0	15.7	6.0	227.1

Source: official data of the Ukrainian Hydrometeorological Center [40], Internet metrostation of Davis, and original data calculated based on the data obtained.

The research site is located in the Dry Steppe of Prysyvashia Province and is represented by agricultural production groups with the following soils dark chestnut slightly deflated sandy, meadow-chernozem slightly saline light loam, meadow-chestnut gleyed light loam.

The following variants of tillage and irrigation technologies were included in the research scheme (i) conventional tillage (CT) without irrigation; (ii) no-till without irrigation; (iii) no-till with drip irrigation (DI); (iv) no-till with subsurface drip irrigation (SDI).

The placement of options in the experiment is consistent. Repetition is three times. The yield was determined by manual harvesting followed by weighing and analysis of parameters. Data from all records analyses and observations were processed using statistical processing. Statistical processing of the obtained results was performed using the program StatSoft Statistica 6.0.

Technological operations were carried out using specially designed equipment depending on the methods of tillage. With no-till, no mechanical operations were performed except for sowing. Conventional tillage technologies included plowing up to 27 cm, and double cultivation up to 10 cm. Corn was sown on April 27, 2021, using of machine complex as New Holland TD5.110 and Marisa-Maschio Gaspardo with a sowing rate of 6.5 pieces/run m (92.86 thousand pieces/ha), row spacing 70 cm to a depth of 5-6 cm. Simultaneously with sowing, urea was applied with a mass fraction of nitrogen equal to 46.2% at the rate of 100 kg/ha. Used for sowing medium-ripe corn hybrid DM Skarb (FAO 330). At the experimental landfill, according to the variants of the experiment under DI and SDI, the moisture regime in the layer of 0-50 cm was observed, equal to 75-80% of the lowest moisture content. Drip irrigation was carried out with the irrigation pipelines on the soil surface at a distance of 1.0 m from each other; SDI with irrigation pipelines at a depth of 0.2 m and a distance of 1.0 m from each other.

RESULTS AND DISCUSSIONS

Positive changes in environmental impact are usually due to the accumulation of plant residues on the surface and in the upper layers of the soil, which reduces surface and internal soil runoff, improves the balance of carbon and other nutrients, and inhibits dehumidification, gas emissions, downstream redistribution. The results of point experiments indicate the effectiveness of no-till and require further study and objective evaluation [29]. The productivity of corn is determined by its genetic potential, the realization of which is achieved by the purposeful, cooperative implementation of technological techniques in accordance with the natural and climatic conditions of the growing area. In arid climatic conditions, irrigation is the most important factor in ensuring the viability of agrocenosis and, accordingly, a factor in obtaining guaranteed crop yields. The results of experimental studies showed that the use of no-till had an advantage over conventional tillage (Figure

1). The lowest productivity of corn was obtained on the variants of CT in conditions of natural moisture and consisted of 7.1 t/ha. The variant of no-till without irrigation increased the grain yield of corn by 0.4 t/ha, which is significant and was confirmed by the results of statistical cultivation (LSD_{05} is 0.35 t/ha).

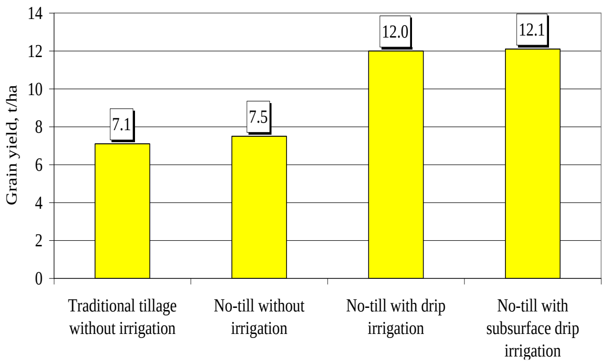

Fig. 1. Corn yield depending on the studied factors
Note: LSD_{05} (tillage) is 0.35 t/ha; LSD_{05} (irrigation) is 0.45 t/ha.
Source: original data calculated based on the data obtained.

A comparison between DI and SDI under no-till showed the absence of a significant difference of 0.1 t/ha and it was within the experimental error. The higher yield was under SDI with no-till and consisted of 12.1 t/ha. There are several reasons for the introduction of no-till as an economic (saving costs for spare parts, fuel and lubricants, and wages), agronomic (improving the water regime of the soil) environmental (reducing CO_2 emissions from the soil by binding carbon to soil organic matter, as well as reduction of soil degradation due to stabilization of erosion processes). The formation of the products price consists of many elements, one of the main of which is the cost of production. Each element of technology used in the cultivation of crops has an ambiguous effect on the value of the cost. Under the conditions of growing corn using CT in the conditions of natural moisture, the cost of production was the highest and amounted to 4,972 UAH/t (Table 2).

Table 2. Economic efficiency of corn cultivation with different methods of tillage and irrigation

Indicators	Conventional tillage without irrigation	No-till without irrigation	No-till with DI	No-till with SDI
Cost of grain, UAH/t	4,972	4,534	3,722	3,780
Growing costs, UAH/ha	35,301	34,008	44,669	45,732
Cost of production, UAH/ha	56,090	59,250	94,800	95,590
Profit, UAH/ha	20,789	25,242	50,131	49,858
The level of production profitability, %	58.9	74.2	112.2	109.0

Source: original data calculated based on the data obtained.

Growing crops in areas where modern technology was used, the figure decreased. This is due to the optimization of conditions for growth and development of culture and, consequently, increase yields. Thus, in areas where no-till was used in the conditions of natural moisture, the cost of corn decreased by 9.7% and amounted to 4,534 UAH/t. Irrigation is a major factor in intensifying agricultural production and a key element in increasing crop productivity in arid climates. The use of no-till with DI made it possible to obtain the main corn products with a cost of 3,722 UAH/t, which is 21.8% less than the previous combination. No-till with SDI slightly increased the cost of grain compared to the no-till with DI by 58 UAH/t is up to 3,780 UAH/t. Net profit, as part of the balance sheet profit of the farm, which remains at its disposal after taxes, fees, deductions, and other mandatory payments to the budget has changed significantly depending on the studied factors. Profit was obtained on all variants of the experiment. The largest profit was obtained on the variants of the experiment, which used no-till with DI and consisted of 50,131 UAH/ha. Also, a slightly lower indicator was obtained on the variants of no-till with SDI of 49,858 UAH/ha, which is less than the previous variant by 273 UAH/ha. The lowest profit of 20,789 UAH/ha was obtained under conventional technologies in non-irrigated conditions, which is 2.4 times less in comparison with other variants. In the conditions of application of no-till without irrigation, the indicator of profit made 25,242 UAH/ha. The level of profitability characterizes the economic efficiency of production and the feasibility of introducing new elements of cultivation technology. According to calculations, growing corn without irrigation provides an indicator of 58.9%, which is 26.0 percentage points less than the use of no-till, where it was 74.2%. The maximum values of the production profitability when growing crops under no-till with DI were determined and consisted of 112.2%. When the irrigation technology was replaced by SDI, the level of production profitability decreased by 3.2% and consisted to 109.0%.

CONCLUSIONS

Corn yield varied significantly from the studied parameters of cultivation technology. The highest productivity of 12.1 t/ha was obtained in a variant of no-till with SDI and 12.0 t/ha of no-till with DI. During the statistical processing of the obtained experimental data, no significant difference between the studied variants was found. Carrying out an economic analysis of corn cultivation in the arid climate of the Southern Steppe of Ukraine testifies to the high efficiency of application of the new technologies of tillage and irrigation system. The application of no-till with drip irrigation system allowed to obtain grain with a cost of 3.72 UAH/t, to obtain a profit of 50.13 UAH/ha with a level of production profitability of 112.2%. It should be noted that the use of no-till with the system of subsoil drip irrigation led to slightly lower indicators of economic efficiency of corn growing, under which the level of production profitability was 109.0%.

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