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## **Influence of Farming and Tillage Systems on Available Moisture Reserves of Common Chernozem for Spring Wheat Cultivation**

**Abstract.** Numerous studies by Ukrainian and foreign scientists have proven that one of the limiting factors for obtaining stable crop yields is the reserves of productive moisture in the soil, especially during critical periods of their growth and development. The article presents the results of research on the influence of three farming systems – industrial (control), organic and biological and four variants of basic tillage – ploughing by 20-22 cm (control), chiselling by 20-22 cm, disking by 10-12 cm, disking by 6-8 cm on the reserves of productive moisture in the soil for growing spring durum wheat. The results of the research revealed that the highest moisture reserves in the meter thickness of the soil during the sowing period were obtained by combining the biological system of agriculture and chisel tillage, which made it possible to accumulate 199.1 mm in 2018, 179.6 mm in 2019 and 159.9 mm in 2020 of available moisture in the soil. The use of chisel cultivation in combination with industrial and organic

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farming systems also proved to be beneficial in all years of observation over combinations of ploughing and both variants of disking with these systems. During the growing season in all studied farming systems, no-till farming (chiselling and disking) provided the highest reserves of available moisture in the soil. However, the combination of an organic farming system with 20-22 cm chiselling should be considered the optimal option, which provided 74.0 mm of moisture for the flowering period in 2018, 93.7 and 90.9 mm in 2019 and 90.9 mm in 2020, and during the harvesting period, these figures were 61.0, 67.7 and 61.6 mm, respectively. The yield of spring durum wheat grain in this variant was essentially the highest in the experiment and amounted to 4.6, 6.7 and 5.6 t/ha, respectively

**Keywords:** industrial, organic and biological systems of agriculture, ploughing, chiselling, disking, hydrothermal coefficient, reserves of available moisture in the soil, yield

### RELEVANCE

Scientific and practical experience has established that obtaining stable, high, economically and energetically feasible yields of any agricultural crop with a minimal negative impact on the environment is possible only with the introduction of modern farming systems (Tanchyk S.P., Pavlov O.S., 2013; Artyomov M.P., 2013). One of the central links of any farming system is soil cultivation, the role of which, especially in organic farming, is extremely important in ensuring optimal soil fertility and conditions for plant growth and development (Medvedev V.V. *et al.*, 2019; Tanchyk S.P. *et al.*, 2009).

### ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Scientists have found that in the Right-Bank Forest-Steppe zone, the lack of productive moisture in the soil during critical periods for spring early grain crops causes a decrease in their yield in certain years by 30-50% (Sayko, 2011; Ivashchenko, Rudyk-Ivashchenko, 2011; Tsytsyura, 2017). At present, there has been a gradual decrease in the average annual amount of precipitation for the May-August period, which suggests that the Right-Bank Forest-Steppe is a risky farming zone. Under these conditions, an important aspect is the ability to manage the reserves of

available moisture in the soil (Korniyuchuk, Voronetskaya, 2021).

According to the research of domestic and foreign scientists, the most effective way to preserve and accumulate moisture in the soil is to improve such units of farming systems as tillage, crop rotation system, fertiliser system (Tsylyurik, 2015). In particular, the research of Halvorson *et al.* indicates the undeniable advantage of minimum tillage in terms of the impact on soil moisture reserves and water use efficiency of spring wheat (Halvorson *et al.*, 2019). According to (Johnson *et al.*, 2016; Obalum *et al.*, 2011) surface residues under minimum and conservation tillage can improve soil water and physical properties, conserve soil moisture and increase water use efficiency.

Purpose of the study. Establishment of patterns of formation of productive moisture reserves in typical chernozem depending on farming systems and soil cultivation in spring wheat crops of the Right-Bank Forest-Steppe of Ukraine.

### MATERIALS AND METHODS

The research was conducted during 2018-2020 within the stationary two-factor experiment of the Department of Agriculture and Herbiology of the Agronomic Experimental Station of the

National University of Life and Environmental Sciences of Ukraine, Pshenychne village, Vasylkiv district, Kyiv region.

In the stationary experiment, three variants of the farming system (factor A) and four variants of the main tillage system (factor B) were studied in a short-term rotation of grain-plough crop rotation with the following sequence of crops: soybeans – winter wheat – sunflower – spring wheat – corn for grain.

The content of gradations of the first factor (A) of agricultural systems is compiled on the basis of their resource provision for extended reproduction of soil fertility. The control variant of agricultural systems is the model of industrial agriculture in which the resource support for the programmable productivity of arable land is the application of 12 tons of organic (manure) and 300 kg of the active substance of mineral fertilisers per hectare in crop rotation ( $N_{92}P_{100}K_{108}$ ), including for spring wheat 290 kg/ha of the active substance ( $N_{90}P_{90}K_{100}$ ) and intensive use of recommended pesticides. Sunflower and corn were manured at the rate of 30 t/ha. The index of ecologisation in such a farming system is 25 (300/12), which is evidence of its industrial nature.

The models of organic and biological farming were compared with the control variant. In the case of organic farming, to ensure programmable productivity, 24 t/ha of organic and 150 kg/ha of NPK mineral fertilisers in active substance ( $N_{47}P_{78}K_{25}$ ), in particular, 130 kg/ha of the active substance ( $N_{50}P_{20}K_{60}$ ) for spring wheat. The use of organic fertilisers in crop rotation under this system involved the application of 12 tons of manure per hectare of crop rotation area and 12 t/ha of green manure (white mustard), which were sown after harvesting winter and spring wheat. The application of pesticides in this system is ecologically justified by the criterion of the ecological and economic threshold of the number

of pests. The index of greening agriculture is 6.2 (150/24).

In biological farming, only 24 t/ha of organic fertilisers were used in crop rotation – 12 tons per hectare of manure and 12 t/ha of green manure (white mustard), which were sown after harvesting winter and spring wheat. The index of greening agriculture in this version of the system is 0 (0/24).

Models of farming systems in the stationary experiment by the method of split plots include four variants of basic tillage (factor B) for spring wheat:

- 1) ploughing by 20-22 cm (control);
- 2) chiselling by 20-22 cm;
- 3) disking by 10-12 cm;
- 4) disking by 6-8 cm.

The experiment was based on the split-section method. The plots on which the variants of basic tillage are implemented have a sown area of 280 m<sup>2</sup> (8 × 35 m), and an accounting area – 225 m<sup>2</sup> (7 × 32.1 m). The plots on which the relevant fertiliser and plant protection systems characteristic of certain variants of the farming system are applied have a sown area of 93.6 m<sup>2</sup> (8 × 11.7 m), and the accounting area is 75 m<sup>2</sup> (7 × 10.7 m). The number of repetitions in the experiment is 4. Sowing of spring wheat durum variety Diana was carried out at the onset of physical ripeness of the soil at a temperature of the sowing layer of 2-3°C.

Soil samples to determine the total reserves and available moisture in the soil were taken with a drill from the layers 0-10, 10-20, 20-30, 30-50, 50-70, 70-100 cm before sowing spring wheat, in the flowering phase of the crop and before harvesting (Tanchyk *et al.*, 2013). Grain yield accounting of the crop was carried out in the phase of full ripeness of spring wheat by continuous harvesting from the accounting areas with bringing to 100% purity and standard humidity of each variant in all repetitions separately.

Sowing of spring wheat durum variety Diana was carried out at the onset of physical ripeness of the soil at a temperature of the sowing layer of 2-3°C. During the years of research, this period fell on the end of March – the first decade of April. The seeding rate was 6 million germinating seeds per 1 ha, the seeding depth – 3-4 cm, and row spacing was 15 cm.

Statistical analysis of experimental data was – performed using Excel from MS Office 365 and Statistica 10 software.

## RESULTS

The regime of moisture supply of crops depends primarily on the weather conditions in the years of research. For spring durum wheat, it is important to have a sufficient supply of productive moisture during the sowing period, which is formed mainly due to winter precipitation. This crop requires slightly more available moisture for seed germination and seedlings compared to other early spring cereals. To assess the impact of weather conditions on the reserves of available moisture in the soil, an indicator of the hydrothermal coefficient, which indicates the level of moisture in the territory, is analysed. The adequacy of the HTC with respect to long-term data was assessed by the adequacy indicator ( $K_i$ ). According to the scale, optimal deviations are those with the coefficient of the significance of deviations in the range of  $0 \div \pm 0.3$ ; tendentially overestimated with  $K_i$  in the range of +0.4-1; tendentially reduced –  $K_i$  in the range of -0.4-1;

significantly overestimated –  $K_i$  in the range of +1-2; significantly reduced –  $K_i$  in the range of -1-2; extremely overestimated with  $K_i > +2$  and extremely reduced with  $K_i > -2$ .

The data in Figure and Table 1 show that the years of the research differed in monthly HTC values. The beginning of the growing season of 2018 was characterised by unfavourable moisture conditions. In particular, in April of this year, the HTC was 0.2, thus characterizing the area as desert, which is a significant deviation from the long-term average ( $K_i = -1.3$ ), and May with HTC of 0.7 was very dry, which tended to differ from the long-term average ( $K_i = -0.5$ ). Instead, June and July of this year with HTC indicators of 1.8 and 1.4, respectively, can be attributed to excessively and sufficiently moist months. The month of August can be regarded as unfavourable in terms of moisture (HTC = 0.3), and September with HTC=1.2 was typical ( $K_i = -0.1$ ).

Spring 2019 was radically different from the previous year, as April and May with values of 3.1 and 1.9, respectively, were excessively moist, which is not typical for these months ( $K_i = 1.7$  and 0.8). June and August of this year with HTC indicators of 0.98 and 0.73 were dry, which is typical for this period ( $K_i = -0.2$ ). July with the HTC index of 1.2 was one of the slightly drier months, although it was tendentially more favourable in terms of moisture compared to the long-term average ( $K_i = 0.8$ ). Thus, 2019 was characterised by waterlogged spring months and rather limited moisture in the rest of the growing season (see Table 1, Fig. 1).

**Table 1.** The adequacy ratio of the HTC indicator to the long-term average ( $K_i$ )

Year of research	Months of the vegetation period						Over the vegetation period
	April	May	June	July	August	September	
2018	-1.3	-0.5	0.7	1.2	-0.7	-0.1	-0.3
2019	1.7	0.8	-0.2	0.8	-0.2	-0.6	0.35
2020	1.0	2.0	-0.4	-0.3	-0.5	-0.5	0.05

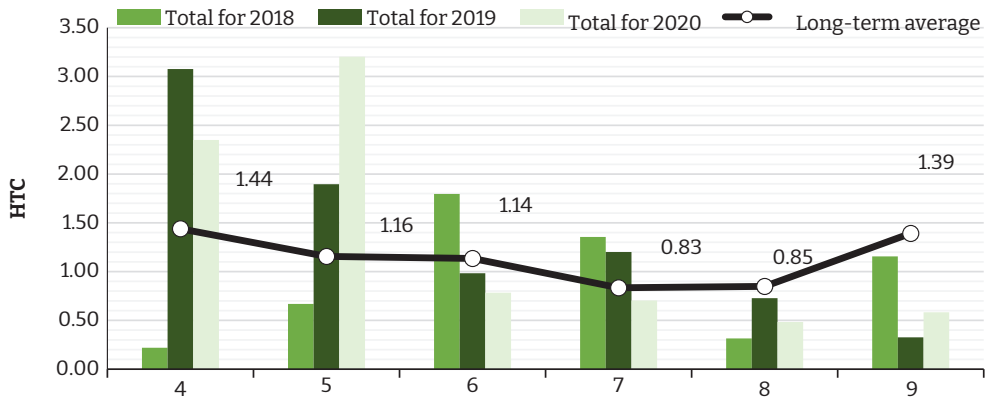


Figure 1. Monthly distribution of HTC, 2018-2020

The vegetation period of 2020 was similar to 2019 in terms of monthly HTC index distribution. April and May of this year were excessively moist with HTC indicators of 2.35 and 3.2, respectively, which is a significant and extreme deviation from the average long-term indicators ( $K_1 = 0.9$  and 2.0). The rest of the months in the vegetation period varied from dry June (HTC 0.78) to very dry July, August and September (HTC 0.7, 0.48, 0.58, respectively), while the aridity of this period was confirmed statistically ( $K_1 = -0.3, -0.5$  and  $-0.5$ ).

Thus, the years of research were different in terms of annual HTC indices. However, it is worth highlighting some of their common features: a tendency or extreme increase in GDD ( $>10^\circ\text{C}$ ) of the growing season against the background of typical precipitation; a variegated pattern of the main weather parameters by months of the growing season (see Fig., Table 1).

The data in Table 2 indicate sufficient reserves of available moisture in the soil for the period of sowing spring wheat – 176.9 mm in the spring of 2018, 164.6 – 2019 and 146.3 mm – 2020 on average in the experiment. At the same time, moisture reserves were closely related to the amount of precipitation during the autumn-winter period. Thus, in the autumn and winter months of 2017-2018, there was 465 mm

of precipitation, in 2018-2019 – 285 mm and in 2019-2020 – 174 mm. The correlation coefficient between the early spring reserves of available moisture and the amount of precipitation in these periods was  $r = 0.97$ .

However, despite the impact of precipitation, the studied factors – cropping systems and basic tillage systems – had an effect on the indicators of available moisture in the soil. Results of the impact of farming systems on the reserves of available moisture revealed the prevalence of biological farming system in all years of determination. In particular, in 2018 the advantage of this variant over the control was 9.4 mm, in 2019 – 2.8, in 2020 – 4.7 mm, which is statistically significant (Table 2).

The effect of cultivation on the accumulation of available moisture in the soil was also significant. No-till cultivation systems – chiselling at 20-22 cm, disking at 10-12 cm and disking at 6-8 cm – created better conditions for better moisture accumulation. Chiselling can be considered the most effective solution, as it provides a significant increase in productive moisture reserves at the time of sowing spring wheat in the range of 10.6-20.1 mm depending on the year. Variants with disking also had a positive effect against the control, but it was significantly lower than chiselling (Table 2).

**Table 2.** The reserves of available moisture in the meter thickness of the soil depending on the studied factors

Agricultural systems (A)	Basic tillage systems (B)	Moisture reserves, mm								
		before sowing			flowering			before harvesting		
		2018	2019	2020	2018	2019	2020	2018	2019	2020
I (St)	P (St)	150.4	158.3	133.0	70.8	72.6	70.4	57.2	63.4	57.7
	C	188.0	169.6	151.0	71.9	73.7	71.5	58.1	64.5	58.7
	D 1	174.4	157.4	140.1	73.4	75.2	73.0	60.7	67.3	61.3
	D 2	181.2	163.5	149.0	72.3	74.1	71.9	58.1	64.5	58.7
O	P (St)	175.1	167.5	140.7	71.7	81.7	79.2	59.3	65.8	59.8
	C	176.7	169.0	150.5	74.0	93.7	90.9	61.0	67.7	61.6
	D 1	175.2	167.5	149.2	75.1	95.1	92.2	62.4	69.2	63.0
	D 2	170.0	162.6	149.6	73.4	93.0	90.2	63.0	69.9	63.6
B	P (St)	178.0	160.6	134.9	72.2	82.2	79.8	55.1	61.1	61.1
	C	199.1	179.6	159.9	74.8	94.7	89.0	56.6	62.8	63.8
	D 1	182.8	164.9	146.9	73.6	93.2	90.4	56.5	62.8	63.8
	D 2	171.6	154.8	150.4	74.7	94.6	91.8	53.7	59.6	62.0
<b>LSD<sub>05</sub> (AB)</b>		<b>4.3</b>	<b>4.1</b>	<b>5.9</b>	<b>1.9</b>	<b>2.1</b>	<b>2.2</b>	<b>2.9</b>	<b>3.2</b>	<b>2.8</b>
On average for agricultural systems (a)										
I		173.5	162.2	143.3	72.1	73.9	71.7	58.5	64.9	59.1
O		174.3	166.7	147.5	73.6	90.9	88.1	61.4	68.1	62.0
B		182.9	165.0	148.0	73.8	91.2	87.7	55.5	61.6	62.7
<b>LSD<sub>05</sub> (A)</b>		<b>2.2</b>	<b>2.0</b>	<b>3.0</b>	<b>0.9</b>	<b>1.1</b>	<b>1.1</b>	<b>1.4</b>	<b>1.6</b>	<b>1.4</b>
On average for basic tillage systems (B)										
P		167.8	162.1	136.2	71.6	78.8	76.5	57.2	63.4	59.6
C		187.9	172.7	153.8	73.6	87.4	83.8	58.6	65.0	61.4
D 1		177.5	163.3	145.4	74.0	87.8	85.2	59.9	66.4	62.7
D 2		174.3	160.3	149.6	73.5	87.2	84.6	58.3	64.7	61.4
<b>LSD<sub>05</sub> (B)</b>		<b>2.5</b>	<b>2.4</b>	<b>3.4</b>	<b>1.1</b>	<b>1.2</b>	<b>1.3</b>	<b>1.7</b>	<b>1.8</b>	<b>1.6</b>

**Note:** I – industrial, O – organic and B – biological farming systems; O – ploughing by 20-22 cm, C – chiselling by 20-22 cm, D 1 – disking by 10-12 cm, D 2 – disking by 6-8 cm

Assessment of the effect of the interaction of factors pointed to the significantly highest moisture reserves for the period of sowing the crop for the combination of the biological system and chisel tillage, which allowed to accumulate in 2018 199.1 mm, 2019 – 179.6 and 2020 – 159.9 mm of available moisture in the soil. The use of chisel cultivation in combination with industrial and organic farming systems also prevailed in all years of observation over combinations of ploughing and both variants of discussions with these systems.

During the vegetation period, the moisture available in the soil is used both for the needs of the crop itself and for physical evaporation from the soil. Assessment of the reserves of productive moisture in the soil during the flowering period of the crop reveals that two years with significant moisture in April and May (2019 and 2020) had a substantial advantage in this parameter in organic and biological farming systems. Thus, in 2019, these systems showed productive moisture reserves in the soil of 90.9 and 91.2 mm, respectively, which is significantly higher than the

industrial one – 73.9 mm. In 2020, organic and biological farming provided 88.1 and 88.7 mm, and industrial – 71.7 mm. In 2018, following the dry spring, the efficiency of these systems was levelled, the moisture reserves in the meter layer of soil were 72.1 mm for industrial, 73.6 – for organic, 73.8 mm – for biological systems. Thus, these data indicate that the resource content of organic and biological farming systems provides more efficient accumulation and preservation of soil moisture in the soil due to precipitation in the spring.

The impact of tillage during the flowering period of spring wheat was manifested in a significant benefit of no-till options over ploughing in all years of observation. However, there were no significant differences between chiselling and disking variants (Table 2).

At the time of harvesting in certain years (2018, 2019), the reserves of available moisture in the soil under the biological farming system were significantly lower than in the industrial and organic systems, which, most likely, was caused by the early, compared to other options,

termination of plant vegetation and increased physical evaporation of moisture from the soil.

The trends for higher moisture reserves in the soil under no-till variants of basic tillage persisted, although the influence of this factor on the time of harvesting was less significant than in the early spring period and flowering of the crop.

Statistical processing of data on spring wheat yield indicates a significant impact of the studied factors on this indicator. On average, for three years of research under the organic farming system, the crop yield was 5.0 t/ha, which is 5.8% higher than the control. Under biological farming, there was a significant decrease in yield, which averaged 44.1% over the years of research. At the same time, this decrease in 2019 and 2020 was more significant – 48.6 and 46.3%, in contrast to 2018, where the yield under this system decreased by 33.2%. In years with excessive moisture in the spring months, such a decrease in spring wheat yield can be associated with a higher degree of weed infestation and pathogen development (Table 3).

**Table 3.** The yield of spring wheat depending on farming systems and basic tillage, t/ha

Agricultural systems (A)	Basic tillage systems (B)	Yield, t/ha			
		2018	2019	2020	On average over 3 years
I (St)	P (St)	3.4	6.4	5.3	5.1
	C	4.1	6.2	5.5	5.3
	D 1	3.3	5.6	4.9	4.6
	D 2	2.9	5.1	4.3	4.1
O	P (St)	3.7	6.5	5.5	5.2
	C	4.6	6.7	5.6	5.6
	D 1	3.4	6.1	5.1	4.8
	D 2	3.1	5.6	4.6	4.4

Table 3, Continued

Agricultural systems (A)	Basic tillage systems (B)	Yield, t/ha			
		2018	2019	2020	On average over 3 years
B	P (St)	2.3	3.3	2.8	2.8
	C	2.8	3.5	2.9	3.1
	D 1	2.3	2.9	2.7	2.6
	D 2	1.8	2.4	2.4	2.2
<b>LSD<sub>05</sub> (AB)</b>		<b>0.22</b>	<b>0.28</b>	<b>0.25</b>	<b>0.25</b>
On average for agricultural systems (A)					
I		3.4	5.8	5.0	4.8
O		3.7	6.2	5.2	5.0
B		2.3	3.0	2.7	2.7
<b>LSD<sub>05</sub> (A)</b>		<b>0.11</b>	<b>0.14</b>	<b>0.12</b>	<b>0.13</b>
On average for basic tillage systems (B)					
P		3.6	5.4	4.5	4.4
C		3.8	5.5	4.7	4.6
D 1		3.0	4.8	4.2	4.0
D 2		2.6	4.4	3.8	3.6
<b>LSD<sub>05</sub> (B)</b>		<b>0.13</b>	<b>0.16</b>	<b>0.14</b>	<b>0.14</b>

## CONCLUSIONS

Among the variants of the second factor, the highest yield of spring wheat was obtained under chisel cultivation, which is by 0.2 t/ha (6.6%) more than the control. In the variant with disking by 10-12 cm, the crop yield was 77% lower than the control. Reducing the disking depth to 6-8 cm led to a decrease in yield by 18.4% compared to the control.

Among the variants combining factors, the highest yield in the experiment on average for all years of observation was obtained for the combination of organic farming system with the variant of chisel tillage by 20-22 cm – 5.6 t/ha, which significantly exceeds the control.

The introduction of the organic farming system in the Right-Bank Forest-Steppe zone of Ukraine in combination with the chisel version of the main tillage by 20-22 cm made it possible to form high reserves of productive moisture in the soil for the period of sowing spring wheat, which in 2018 amounted to 176.7 mm, 2019 – 169.0 and 2020 – 150.5 mm, which is significantly higher than the control. At the same time, this variant was more advantageous in terms of moisture supply during the entire growing season of the crop, which allowed to form the highest yield of spring wheat in the experiment at the level of 5.6 t/ha on average over three years.

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## **Вплив систем землеробства та обробітку ґрунту на запаси доступної вологи чорнозему звичайного за вирощування пшениці ярої**

**Анотація.** Численними дослідженнями українських і зарубіжних вчених доведено, що одним із лімітуючих факторів отримання стабільних урожаїв сільськогосподарських культур є запаси продуктивної вологи в ґрунті, особливо в критичні періоди їх росту і розвитку. У статті наведено результати досліджень впливу трьох систем землеробства - індустріальної (контроль), органічної та біологічної та чотирьох варіантів основного обробітку ґрунту - оранки на 20-22 см (контроль), чизелювання на 20-22 см, дискування на 10-12 см, дискування на 6-8 см на запаси продуктивної вологи в ґрунті за вирощування пшениці твердої ярої. Результати досліджень показали, що найвищі запаси вологи в метровій товщі ґрунту на період сівби отримано за поєднання біологічної системи землеробства та чизельного обробітку, що дало змогу накопичити 199,1 мм у 2018 р., 179,6 мм у 2019 р. та 159,9 мм у 2020 р. доступної вологи в ґрунті. Застосування чизельного обробітку в поєднанні з індустріальною та органічною системами землеробства також виявилось переважним у всі роки спостережень над поєднаннями оранки та обома варіантами дискування з цими системами. Протягом вегетаційного періоду в усіх досліджуваних системах землеробства нульовий обробіток (чизелювання та дискування) забезпечував найвищі запаси доступної вологи в ґрунті. Проте оптимальним варіантом слід вважати поєднання органічної системи землеробства з чизелюванням на 20-22 см, яке забезпечило на період цвітіння 74,0 мм вологи у 2018 році, 93,7 і 90,9 мм у 2019 році та 90,9 мм у 2020 році, а на період збирання врожаю ці показники становили 61,0, 67,7 і 61,6 мм відповідно. Урожайність зерна пшениці твердої ярої в цьому варіанті була практично найвищою в досліді і становила 4,6, 6,7 та 5,6 т/га відповідно

**Ключові слова:** індустріальна, органічна та біологічна системи землеробства, оранка, чизелювання, дискування, гідротермічний коефіцієнт, запаси доступної вологи в ґрунті, урожайність