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Efficiency of winter wheat with various technologies of impact on the soil

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Abstract. The paper discusses technologies for cultivating winter wheat in many years of experience, which make it possible to assess the impact of the main methods of tillage (under certain weather conditions) on its yield. Studies on the cultivation of winter wheat were carried out on chernozem by an ordinary carbonate heavy loader. Various tillage technologies have been studied. With conventional technology, the main soil treatment was carried out by the surface method, the fine method and the dump method. With zero technology, sowing was carried out in untreated soil. During the tests, meteorological conditions were taken into account: the amount of precipitation and the average annual air temperature. Deviation of meteorological parameters from the norm is justified. It was determined that the cultivation of winter wheat partially occurred in the dry period from 2017-2018 years to 2021-2022 year due to lack of precipitation and elevated temperatures.

1 Introduction

Winter wheat is a valuable crop that ensures the food security of the population and the self-sufficiency of the economy of the region in particular and the country as a whole. The vulnerability of winter wheat yields to climatic conditions poses a significant threat to the productivity of domestic agricultural enterprises. In previous studies to identify the relationship between crop productivity and hydrothermal soil parameters, taking into account the climatic conditions of the environment, they show that droughts, especially prolonged ones, depress the physiological systems of wheat plants, affect the speed of vegetation phases regardless of the genetic potential of the variety [1].

In breeding, the solved tasks of a significant hereditary increase in drought resistance of winter wheat are limited by the canonically established gene-centric approach and approaches of molecular genetics [2]. Therefore, while breeders are working on solving the problem of breeding stable drought-resistant varieties, modern agricultural producers in rain-fed agriculture have to be content with cultivating winter wheat with available varieties that have proven themselves to be drought-resistant.

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In conditions of drought, the yield of winter wheat is especially susceptible to the slightest changes in climatic conditions, high temperatures, coupled with low humidity, significantly reduce the productivity of its crops [3-4]. Depending on which phase of the vegetation dry conditions occur, the formation of a productive stem, the formation of grains in the ear or the filling of grain suffer [5-6].

However, genetically drought-resistant varieties are also exposed to adverse environmental factors. It follows that productivity is determined not only by genetically determined quantitative characteristics, but also by the emergence of the "plant genotype – environment" system. According to Dragavtsev V.A. [7], the share of genetic variability in productivity components is manifested at the level of 10-20%, while the share of environmental variability can reach 80-90%. This means that any limiting environmental factor can affect the spectrum and number of genes, and as a result

affect the final result – crop yield and crop quality.

There is a wide variety of limiting factors, and their combination in the process of plant vegetation gives unfavorable forecasts. The most pronounced limiting environmental factors limiting the growth and development of plants are precipitation, air temperature, and humidity. These factors have a particularly acute effect on non-irrigated soils in arid or semi-arid climates [8-9].

To achieve economic efficiency in the development of optimal crop cultivation technology, each specific farm relies on available material and technical resources and experience in the production of crop products, taking into account the agroecological requirements of the crop and variety to the growing conditions [10-12].

The technology of cultivation of agricultural crops is a set of closely related agricultural techniques aimed at creating favorable conditions for the growth and development of plants.

The technological cycle of cultivation originates from the moment the field is cleared from the predecessor to the harvest inclusive. During the entire cycle, basic and pre-sowing tillage is carried out, seeds are prepared for sowing, fertilizers and sowing are carried out, as plants grow and develop, care work is carried out to combat diseases and pests, in order to maintain an optimal agrophysical state of the soil, soil cultivation is carried out simultaneously getting rid of weeds, the cycle ends with harvesting.

2 Analysis of literary data and statement of the problem

In the cycle of classical crop cultivation technology, tillage is usually based on a traditional farming system, the essence of which is regular annual tillage. Regularity refers to all stages of tillage during the technology cycle. This includes stubble peeling, basic tillage, and pre-sowing with care cultivation of the soil. However, the dominant place in the farming system is given to the method of basic tillage. It is the main tillage, selected taking into account the cultivated crop and its predecessor, climatic and soil conditions, that aims to create favorable conditions for plant growth and development due to soil loosening [13-14].

The main loosening of the soil is carried out by the working bodies of tillage equipment, and depending on the depth of tillage, the configuration of the working bodies and the way they affect the soil, the name of the main method of tillage is determined. Hence, the main tillage can be dump or non-dump, layered or flat-cut, surface or shallow, etc. Combined tillage is more often used, which allows for differentiated deep loosening in one pass of the unit simultaneously with mulching and compaction of the upper soil layer.

The advantage of using any basic method of tillage is the formation of a loose soil structure. In the treated volume of soil, spatial and temporal changes in the physical and chemical parameters of the soil occur. Soil aggregates interconnected in layers acquire a soil skeleton with a chaotic distribution in the inter-aggregate space with macro- and micropores. Under such conditions, the thermal diffusion process contributes to the long-term preservation of soil moisture. At the same time, the process itself is interconnected with atmospheric phenomena.

In arid conditions, fluctuations in seasonal, daytime and nighttime temperatures of air and soil determine the magnitude and direction of movement of soil moisture inside the soil layer in the form of soil vapor [15]. In this regard, tillage should ensure the movement of moisture inside the soil layer and at the same time prevent evapotranspiration. The presence of a mulching layer on the soil surface from crop residues contributes to moisture accumulation, which is especially important for regions with arid climates. In the treated soil, the density and hardness of the soil decreases, weeds completely or partially die.

In general, the arid climate, insufficient and unstable moisture during the growing season of plants encourage the search for new solutions in the cultivation of crops aimed at resource conservation, especially such a resource as soil moisture, which is basically a limiting factor.

In this regard, in the last three decades, a new approach to crop cultivation with a focus on resource conservation in combination with the economic efficiency of cultivation technology has become popular in Russia.

This approach in the cultivation of crops implies "zero" tillage. This type of processing is an agriculture technique in which the full cycle of crop cultivation technology takes place without prior basic tillage (i.e., any loosening of the soil is completely excluded) in order to conserve moisture by preserving the naturally formed soil structure. Direct sowing of seeds is carried out in untreated soil by means of special sowing units equipped with disc coulters with colters. If zero tillage is used in cultivation technology for a long time (4 years or more) [16], then such crop cultivation technology is qualified as zero (No till technology). The advantage of this technology is to reduce soil erosion processes and moisture conservation by preserving plant residues (stubble) on the field surface from the previous crop, as well as to reduce costs and reduce working time due to direct sowing [16-17].

In addition, there is an opinion that the long-term use of zero technology leads to the restoration of soil fertility by reducing soil degradation due to wind and water erosion, since agronomic valuable soil aggregates remain preserved under the cover of plant residues [10]. At the same time, the biological activity of the soil increases as a result of the stability of its structure [18]. In such soil, effective infiltration of water into the lower layers is observed, which contributes to the accumulation of soil moisture, and its preservation is facilitated by a cover from a layer of crop residues. In this technology, weed control has been mechanically replaced by chemical control – herbicides [19]. And the method of mechanical loosening has been replaced by a competent crop rotation, in which crops with taproot and fibrous root systems alternate, contributing to the biological self-healing of soil layers [20].

Summarizing the above, it follows that the production of winter wheat in arid conditions with insufficient and unstable moisture is a laborious process associated with risks depending on the weather and climatic conditions of each year.

It is known that the resulting indicator of any crop cultivation technology is yield. When crop yields are kept at a consistently high level with high quality and technological indicators of products, they talk about the effective use of cultivation technology, which could be adapted to the agro-climatic potential of a particular agricultural landscape.

It is impossible to determine the patterns of increasing the yield and quality of agricultural products in any other way than by conducting long-term experimental studies in real soil and climatic conditions. Only as a result of a field experiment can a connection be established between the studied properties of crops and the means of influencing them, since there are a number of issues that cannot be studied at all outside the boundaries of

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field experience. These issues include, for example, the system of tillage and plant care, crop rotation, the use of fertilizers, etc.

The main accents in the technology of winter wheat cultivation were made on the study of the main methods of tillage preparing the soil as the main agrophones for sowing, differing in depth and type of processing and in the unit used in the prevailing agrometeorological conditions of each individual agricultural year of the study.

2.1 The purpose of the study

The purpose of the study is to study the technologies of winter wheat cultivation in many years of experience and to assess the impact of the main methods of tillage (under prevailing weather conditions) on its yield.

3 Materials and methods

To study traditional and zero cultivation technologies, as well as the impact of tillage methods on winter wheat yields, technological experience was laid in the fields of the Donskoy Agricultural Research Center from 2013 to 2022.

The laying of a field stationary long-term experience and the formation of fixed allotment areas was carried out in 2013. The soil of the experimental site is ordinary carbonate heavy loamy black soil. The content of humus in the arable soil layer is 3.2%, Ph_2O_5 – 19, -25.1 mg / kg, K_2O – 334-339 mg / kg of soil, pH - 7.1.

The scheme of the stationary experiment is shown in Figure 1. The crop rotation is four-field: winter wheat, spring barley, peas and soybeans. The total area of all experimental plots is 4.3 hectares, and the size of each winter wheat was peas.

In traditional technology, they relied on the classical farming system, therefore, three variants of the main method of tillage were chosen, which provided agrophones for wheat cultivation: a surface method using a heavy disk harrow B7T, a shallow method using a combined unit – KUM-4, a dump method or classic plowing using a plow – PN-5-35. In zero technology (No Till), sowing of winter wheat was carried out with a direct sowing drill "Don 114".

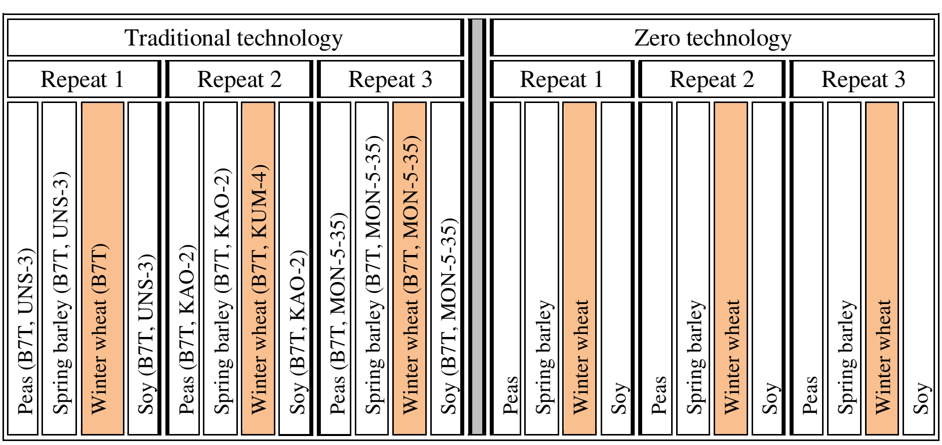

Fig. 1. The scheme of the stationary experience.

In a variant of the experiment using surface tillage (harrowing), the B7T tillage unit was used in two tracks, then pre-sowing cultivation was carried out. In the case of high soil contamination, harrowing might be required for the third time. The working bodies of the

B7T unit are disk batteries arranged in two rows alternately with an adjustable angle of attack. The B7T unit performs one tillage operation of surface loosening of the soil. The technological process of tillage consists of a harrowing operation to a depth of 10 cm. The working bodies are represented by solid spherical disks. When passing through the field, the discs cut out the soil layers in the form of chips, leaving behind a grooved bottom. At the same time, the root system of weeds and plant residues from the previous crop are being pruned. The discs successfully cope with the crumbling of blocks when using the B7T unit for harrowing the field after deep tillage.

In the variant of the experiment, a combined tillage unit KUM-4 in one track was used to prepare an agrophone with combined shallow tillage, and pre-sowing cultivation was carried out before sowing winter wheat. The KUM-4 unit combined operations of shallow layer-by-layer processing to a depth of up to 16 cm in one pass through the field with simultaneous pruning of weeds, crumbling of boulders, leveling, compaction and mulching of the surface soil layer. This is a multi-operational unit, the working bodies of which are spherical disk batteries, followed by pointed paws, then ripper rollers are located and a mulching roller is located at the end. The technological process of tillage of the combined unit KUM-4 consists of several operations performed simultaneously. The working bodies in the form of a battery of disks, located first on the frame of the unit, loosen the soil to a depth of 6-7 cm, grind the plant remains of stubble and destroy weeds. At the same time, a network of cracks is formed in the underlying soil horizons that violate the solidity of the soil layer. Flat-cutting working bodies in the form of paws with a grip width of 400 mm each are located behind the disk batteries, which loosen the soil to a set depth of up to 14-16 cm. As a result of their work, the root system of weeds is pruned and the soil layer with already laid cracks is loosened to the required depth and a smooth bottom of the furrow is formed with the separation of pulverized soil particles and valuable soil aggregates to the bottom of the furrow. As a result, the fertile soil layer is preserved, and erosion processes are significantly reduced. Following the plane-cutting paws, a lump-crushing roller comes into operation, which ensures the crushing of the remaining large soil lumps on the surface of the field and forms a subcompaction of the treated layer. The final technological operation of the KUM-4 unit is performed by a mulching roller. Its task is to form a compacted seedbed for seeds with simultaneous mulching of the compacted topsoil. The use of the combined KUM-4 unit allows you to bring the soil to a pre-sowing state in one pass. The alternation of loose and compacted layers with separated soil ensures the preservation of soil moisture, and also contributes to the accumulation of moisture by condensation during the dry period.

In the variant of the experiment for the preparation of an agrophone with a dump method, soil treatment with a PN5-35 plow was carried out to a depth of 22 cm immediately after harvesting the previous crop. Subsequently, before sowing, the soil was cultivated to the depth of sowing seeds. As a result, a loose soil structure was formed, sprouted weeds were removed, and a compacted soil bed for seeds was formed.

In the variant of the experiment with zero No Till technology, the effect on the soil was single and occurred during sowing. The main impact on the soil was exerted by the coulter group of the Don 114 seeder. Technological operations of tillage and sowing were carried out in one pass of the drill. The colters in front cut through the crop residues, thereby creating a furrow and microprocessing the soil. Following the colter, two-disc coulters laid the seeds to a set depth, and the packing shank pressed them to the bottom of the furrow. Subsequently, the furrow was covered with double trapezoidal covering wheels.

During long-term observations, the meteorological parameters of each agricultural year during the growing season of winter wheat were taken into account, which included the average annual air temperature and the amount of precipitation per year.

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Field and laboratory studies were performed in accordance with the Methodology of the state variety testing of agricultural crops [21]. Sheaves of plants from the accounting plot were selected in fourfold repetition to identify the biological yield of winter wheat.

4 Results and Discussion

The prevailing meteorological parameters for the long-term observed period are shown in the figures (Figures 2 and 3). Table 1 shows the deviations of the average annual air temperature and precipitation from the established norm of each parameter.

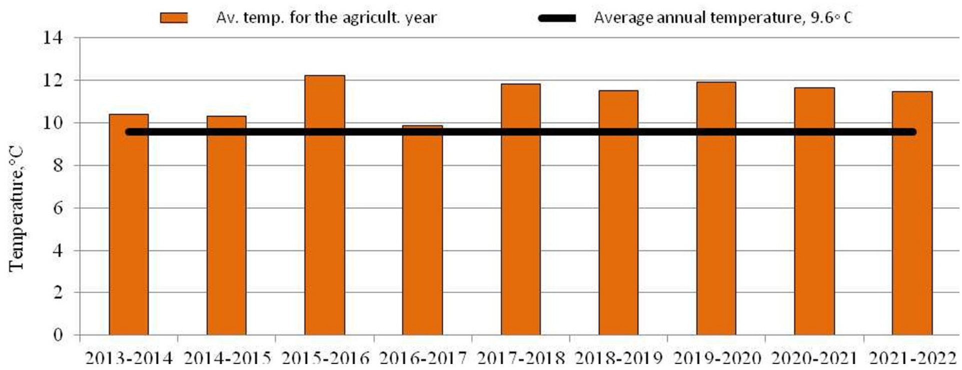

Fig. 2. Meteorological parameters: air temperature during the growing season of winter wheat.

A significant shortage of precipitation was noted in the same last 5 years of research. Years with a significant precipitation deficit of 136.3 mm and 130.6 mm were recorded, respectively, 2017-2018 agr. year and 2019-2020 agr. year.

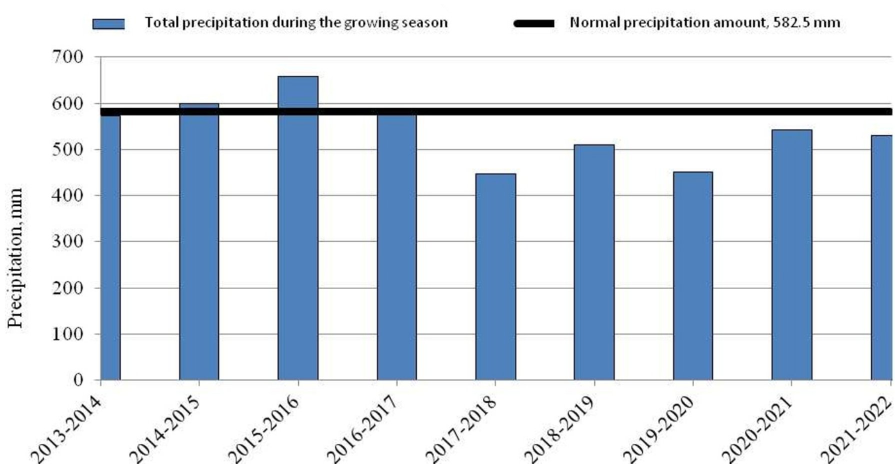

Fig. 3. Meteorological parameters: the amount of precipitation during the growing season of winter wheat.

As a result of the analysis of the presented figures and the obtained deviations of meteorological parameters, it was found that the temperature regime of each agricultural year exceeded the average annual norm. Prolonged deviations with temperature exceeding were established during the last 5 years from 2017-2018 to 2021-2022 C.H., when there was an excess of air temperature by 1.9-2.3 °C.

Table 1. Deviations of meteorological parameters during the agricultural year.

Deviations	The rate for the year	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
From the average annual temperature, °C	9.6	0.8	0.7	2.7	0.3	2.2	1.9	2.3	2.0	1.9
From the norm of precipitation, mm	582.4	-10.5	17.9	76.5	-4.3	-136.3	-71.8	-130.6	-39.9	-52.6

As a result of the analysis of the revealed deviations of the average annual temperature and precipitation from the norm (Table 1), it was found that the research period from 2017 to 2022 can be attributed to extremely arid due to a combination of high air temperatures and a shortage of precipitation.

During the nine agricultural years of winter wheat cultivation, two full-fledged crop rotation took place. Depending on the method of tillage for the preparation of the agrophone embedded in the cultivation technology, the yield of winter wheat was obtained, which is reflected in Table 2.

Table 2. Yield of winter wheat depending on the method of tillage, t/ha.

The Way of tillage (unit)	Years										Deviation	
	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average	%	t/ha
Surface (B7T)	5.76	7.35	5.96	9.59	3.08	5.64	4.42	4.74	7.59	6.01	99.67	-0.02
Small (KUM-4)	5.70	7.12	4.38	8.03	2.7	6.05	4.15	4.81	6.98	5.55	91.92	-0.49
Dump (MON-5-35)	5.58	6.71	5.79	8.56	3.06	6.41	4.58	4.99	7.62	5.92	98.14	-0.11
Zero (No Till)	6.18	7.52	4.72	9.91	2.62	5.57	5.14	5.44	7.21	6.03	-	-

As a result of the analysis of the data in Table 2, it was found that for 9 years of research, the highest yield of winter wheat of 6.03 t/ha was provided by zero tillage in No Till technology. This is despite the fact that surface and dump tillage to ensure the yield of winter wheat were inferior only by 0.33-1.86%, which allows them to be considered equivalent to zero tillage. The lowest yield of 5.55 t/ha was established with shallow tillage and was 8.08% lower than zero.

Analyzing the yield of winter wheat at various agrophone for each agricultural year and meteorological conditions for the growing season of winter wheat, it was determined that not every dry year leads to low yields, and not every rainy year provides high yields. However, there is no doubt that it is possible to manage yields through the introduction of one or another method of tillage, which, during the basic preparation of the agrophone, would provoke the accumulation of soil moisture during precipitation and its preservation during drought, as well as through the structure of the arable layer, optimized soil moisture consumption conditions for plants.

Based on the results of long-term observations of the influence of the tillage method on winter wheat yields, an assessment was carried out and those processing methods that provided minimum and maximum yields were identified by year. The data systematized in this way are shown in Table 3.

The analysis of table 3 revealed that over a nine–year observation period, a shallow tillage method provided the lowest yield for 4 years and did not provide high yields for a single year, low yields were obtained for 2 years at an agrophone with dump tillage and high yields for 2 years, an agrophone with zero tillage provided low yields for 2 years, and high yields within 5 years, at the agrophone with surface tillage, low yields were obtained within 1 year, and high yields within 2 years.

In arid conditions from 2017-2018 to 2021-2022, zero technology with direct sowing twice in a row provided high yields of winter wheat of 5.14 t/ha and 5.44 t/ha in 2020 and 2021, respectively, and twice in a row low yields of 2.62 t/ha and 5.57 t/ha in 2018 and 2019 accordingly.

Table 3. Systematization of winter wheat yields, depending on the methods of tillage.

The Way processing	**The Agricultural year**									**Total, years**
	2013-2014	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**	
Minimum yield, t/ha										
The surface								4.74		1
Small			4.38	8.03			4.15		6.98	4
Dump	5.58	6.71								2
Null					2.62	5.57				2
Maximum yield, t/ha										
The surface			5.96		3.08					2
Small										0
Dump						6.41			7.62	2
Null	6.18	7.52		9.91			5.14	5.44		5

In the traditional cultivation technology under the classical farming system, high yields were obtained at the agrophone with a dump treatment method of 6.41 t/ha and 7.62 t/ha in 2019 and 2022, respectively, and at the agrophone with a surface treatment method of 3.08 t/ha in 2018. Low yields of 4.15 t/ha and 6.98t/ha in traditional cultivation technology were obtained at the agrophone with surface tillage in 2020 and 2022, respectively, and at the agrophone with surface tillage – 4.74 in 2021.

5 Conclusion

The correlation analysis carried out between the amount of precipitation during the growing season of winter wheat and its yield on agrophone prepared by various methods of tillage revealed a high positive relationship in the variants with surface and dump tillage r=0.57 and r=0.52, respectively, and an average positive relationship in the variants with shallow and zero tillage r=0.45 and r=0.43 accordingly.

The most severe negative impact on the yield of winter wheat over a long-term observation period was caused by the average annual air temperature, since the value of the correlation coefficient for an agrophone with zero tillage was r =- 0.80, and on agrophones with surface, shallow and dump tillage, the correlation coefficient was r = -0.70, r = -0.76, r = -0.60, respectively.

In general, the general trend in the yield of winter wheat over a long-term observation period revealed its dependence on the main method of processing under prevailing meteorological conditions. In arid conditions, from 2017 to 2022 agricultural years, the maximum yield was obtained using zero technology and traditional technology with dump tillage.

It was revealed that in long-term studies, zero technology provided the highest yield of winter wheat of 6.03 t/ha. In traditional technology, surface and dump tillage to ensure the yield of winter wheat was inferior to zero by 0.33-1.86%, shallow tillage was inferior by 8.08%. After systematization of the maximum and minimum values of wheat yield, it was established that during many years of research, the zero technology provided the highest yield for 5 years, and the traditional one for 4 years.

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