Influence of technology without tillage on indicators of soil fertility in arid conditions of the South of Russia

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Abstract. Winter wheat is the main crop in the Stavropol Territory. Today, the grain crops cover an area of more than 1.9 million hectares. However, the cost of grain production is constantly growing. This leads to a decrease in the profitability of its cultivation. Agricultural field cultivation enterprises are moving from traditional to more resource-saving technologies - technology without tillage. This technology involves growing crops without tillage. In the Stavropol Territory and its arid zone, the technology has not been sufficiently studied for its widespread introduction into production. In this regard, the cultivation of winter wheat using new technology is of scientific and practical interest to research its influence on the germination of fields and the productivity of the main cash crop. Therefore, special attention is paid to the influence of No-till on the agrophysical and agrochemical parameters of dark chestnut soils and crop rotation links in an arid climate. Research was conducted on the territory of the Agrokholeoprodukt Company, located within the borders of the Stavropol Territory. Sowing winter wheat is carried out using John Deere 1890, which allows sowing crops with the simultaneous supply of seed fertilizer. Agrochemical monitoring of the soil was carried out on the basis of the Stavropol Agrochemical Center. Monitoring of meteorological parameters was stationary in the field. Thus, the use of the No-till technology for 2017-2019 ensured the formation of winter wheat productivity in the range of 40.7-49.8 kg/ha. In order to stabilize the productivity of winter wheat attention should be paid to the dynamics of changes in agrochemical parameters: the content of humus and macronutrients in the soil. Regression analysis showed a close relationship between productivity and these values. The use of such precursors as chickpeas and sunflowers in grain rotations contributes to the softening and improvement of the agrophysical properties of dark chestnut soils.

1. Introduction
The concepts of the applied technologies (traditional, minimal, zero) for growing winter wheat in the South of Russia are the optimization of technological processes based on the use of scientific knowledge about the patterns of crop growth, the formation of crop productivity, the biological response of new varieties to the action of biotic, abiotic and production factors. As a result of their implementation, models and areas of resource and energy conservation in technologies for growing winter crops are being formed. Special attention among technologies is paid to zero tillage [1, 2].

The main criterion for the growth and development of winter wheat in the arid zone of southern Russia is the agrophysical and agrochemical properties of the soil, the variability of which is carried out
under the influence of precursors, varieties and tillage. They determine the distribution of the root system in soil layers and the productivity level of the cultivated crop [3, 4, 5].

Zero technology provides for direct sowing of seeds in soil previously treated with herbicides. The decisive factor determining the success of the No-till application is the needs to take into account the main features and properties of soils (compaction resistance, drainage, humus content and mobile forms of nutrients) [6, 7].

In the No-till technology it is important to control and regulate the level of coverage of the soil surface with crop residues, which reduces the effects of drought and water erosion, soil crust formation, soil degumification, soil compaction, and also preserves soil moisture, forms a natural snow retention and nutrient medium for soil fauna. When applying the No-till technology the combination of strip sowing, fertilizing and rolling in one pass is carried out, yield increases, fuel consumption is reduced by up to 60%, labor costs are minimized, costs of equipment acquisition and forest and irrigation improvement are reduced to 50% in the arid zone [8].

However, without a scientifically based assessment of the suitability of soils for zero tillage, its use may pose a certain risk and give negative agronomic, economic and environmental results. Along with the positive aspects of the application of the technology, there are disadvantages: deterioration of the phytosanitary situation (including an increase in mouse-like rodents), a decrease in the content of humus, weediness of crops, etc. [9].

2. Problem statement

Soil fertility is the basis for food stability because 95 % of production is directly or indirectly related to the soil. The use of resource-saving technologies allows to stabilize soil indicators and sometimes leads to its increase [10, 11].

The use of traditional technology has led to the formation of eroded (2.2 %) and deflated (13.3 %) lands. The balance of nutrients in the arable land was again negative and returned to the level of the 1960s.

In order to create a rational system for using the land Fund in domestic science and production, there is a contradictory attitude to replacing the traditional technology with a new one – the technology without tillage [12]. A number of authors give examples of its effective development and impact on soil fertility and productivity of cultivated crops. The presence of a large number of crop residues reduces the effectiveness of nitrogen fertilization by the scattered method and creates a danger of waterlogging the arable layer. The disadvantage of the technology is the high purchase price of the main technical means-direct seeding drills. In addition, the application of technology requires a high level of qualification of agronomic and technical personnel, etc. [13, 14].

3. Research questions

The research was conducted from 2017 to 2019. The field experiments were carried out in the arid climatic conditions of the Stavropol Territory. The average annual rainfall was 506 mm; the average annual air temperature was 10.1 °C [15]. The soil cover of land use "Agrokhleboproduct" is represented mainly by dark chestnut soils, which are characterized by low humus content (2.61-2.70 %), high content of mobile phosphorus (33.2-37.0 mg/kg), exchange potassium (364.5-420.3 mg/kg). The reaction of the soil solution in the upper horizons of the soil is alkaline in the range from 7.7 to 7.9.

The experiment is placed in 3-fold repetition, the area of one plot is 500 m². Studied links of crop rotation are sunflower – winter wheat, chickpeas-winter wheat.

4. Purpose of the study

The purpose of the research was to research the effect of the technology without tillage on the agrophysical and agrochemical parameters of dark chestnut soils during the cultivation of winter wheat in the arid zone.
5. Research methods

The object of research is the dynamics of the parameters of soil fertility. The subject of the research is the elements of the technology without tillage with the help of which various technological operations are carried out. They are presented in table 1.

Table 1. Technological operations of the technology without tillage when cultivating winter wheat.

| Technological operation                              | Application rate | Composition of the agricultural equipment |
|-------------------------------------------------------|------------------|--------------------------------------------|
| Presowing treatment with herbicides (Sprut Extra)      | 2 l/ha           | Self-propelled sprayer Caffini              |
| Sowing winter wheat                                    | 210 kg/ha        | Buhler                                      |
| Entering sowing fertilizer (ammonium nitrate)         | 100 kg/ha        | Buhler                                      |
| Early spring top dressing (ammonium nitrate)          | 100 kg/ha        | John Deere 1890                            |
| Application of foliar application (carbamide-ammonia mixture) | 100 kg/ha       | MTZ 80+ Trailed sprayer 2000               |
| Herbicidal treatment (Ballerina)                      | 0.4 l/ha         | MTZ 80+ Trailed sprayer 2000               |
| First fungicidal treatment (Altosuper)                | 0.5 l/ha         | MTZ 80+ Trailed sprayer 2000               |
| Second fungicidal treatment (Kolosal Pro)             | 0.4 l/ha         | MTZ 80+ Trailed sprayer 2000               |
| Insecticidal treatment (Borey)                        | 0.1 l/ha         | MTZ 80+ Trailed sprayer 2000               |
| Harvesting winter wheat                               |                  | Harvester CLAAS                             |

The No-till system in the agricultural enterprise Agrokhleboprod JSC was introduced in 2014. In the first three years of applying the technology, it cannot be considered zero technology (direct sowing). Only in the fourth year technology began to show itself as the technology without tillage. Before mastering the technology, loosening was carried out below the depth of the compacted soil layer (23-25 cm) and surface leveling.

Soil monitoring was carried out on the basis of the agrochemical center "Stavropol" and the laboratory of agrochemical analysis of the Stavropol state agrarian University. Determination of the soil density and the reserve of productive moisture was carried out according to the method of B. A. Dospekhov, organic matter - according to the method of Tyurin, mobile compounds of phosphorus and potassium - according to Machigin, nitrogen content-GOST 26951-86.

6. Findings

This technology becomes a farming system only taking into account the selection of crops and their placement in the crop rotation, since the issues of preserving and increasing the fertility of dark chestnut soils, protecting them from wind and water erosion, moisture accumulation, etc. are resolved. Preservation of atmospheric precipitation in the soil allowed the agricultural enterprise to abandon pure steam and expand the range of cultivated crops (table 2). When developing grain-cultivated crop rotation, the precursors were selected: sunflower and chickpeas, taking into account climatic conditions, the market and the price of cultivation.

Table 2. The effect of the No-till technology and the precursor on the productive moisture content in winter wheat crops in a meter soil layer, mm (average for 2017-2019).

| Technology  | Predecessor | Growth phases before sowing | exit to a tube | full ripeness |
|-------------|-------------|-----------------------------|----------------|---------------|
| No-till     | Chickpea    | 64.7                        | 114.5          | 49.2          |
|             | Sunflower   | 56.4                        | 93.7           | 44.0          |
On average, the supply of productive moisture for the research period in the meter-long soil layer before sowing winter wheat after chickpea was 64.7 mm and sunflower - 56.4 mm. By the phase of full ripeness a decrease in the content of productive moisture is observed respectively to 49.2 mm and 44.0 mm. On average, for 3 years the supply of productive moisture ensured the appearance of timely seedlings due to plant residues remaining on the surface of the fields after harvesting cultivated crops. Therefore, a prerequisite for increasing the productivity of winter wheat is the grinding of crop residues and their uniform distribution over the field surface.

In the arid zone before sowing winter wheat the soil density in the top layer (0-10 cm) after chickpea is 1.17 g/cm³ and sunflower - 1.08 g/cm³ (table 3). During the spring resumption of the growing season of winter wheat the soil density increases and by the phase of full ripeness - even more compacted.

Table 3. The effect of the No-till technology and precursors on soil density in winter wheat crops, g/cm³ (average for 2017-2019).

| Technology  | Predecessor  | Soil layer, cm | Growth phases |  |  |  |
|-------------|--------------|----------------|---------------|--|--|--|
|             | Chickpea     | 0-10           | 1.17          | 1.19 | 1.14 |
|             |              | 10-20          | 1.24          | 1.18 | 1.21 |
|             |              | 20-30          | 1.21          | 1.24 | 1.29 |
|             | Sunflower    | 10-20          | 1.24          | 1.29 | 1.22 |
|             |              | 20-30          | 1.27          | 1.35 | 1.33 |

Particular attention in the agricultural enterprise was paid to the use of mineral fertilizers. To develop the fertilizer system agrochemical parameters were determined: mobile phosphorus, nitrogen and metabolic potassium exchange (table 4).

Table 4. The effect of the No-till technology and precursors on the agrochemical condition of the soil (0-20 cm) and yield of winter wheat (average for 2017-2019).

| Year | The content of agrochemical indicators | Productivity, c/ha |
|------|----------------------------------------|---------------------|
|      | pH           | humus, % | N, mg·kg⁻¹ | P₂O₅, mg·kg⁻¹ | K₂O, mg·kg⁻¹ |  |
|      | Predecessor - chickpea |  |  |  |  |  |
| 2017 | 8.1          | 2.70      | 14.0       | 34.8           | 413.3        | 49.8 |
| 2018 | 7.8          | 2.69      | 13.9       | 38.7           | 402.3        | 46.8 |
| 2019 | 7.9          | 2.69      | 13.8       | 37.3           | 386.0        | 43.5 |
|      | Predecessor - sunflower |  |  |  |  |  |
| 2017 | 7.8          | 2.63      | 13.6       | 32.3           | 372.0        | 47.4 |
| 2018 | 7.8          | 2.62      | 13.4       | 34.2           | 361.0        | 45.0 |
| 2019 | 7.5          | 2.61      | 13.2       | 33.2           | 349.0        | 40.7 |
| 2017 | 7.8          | 2.63      | 13.6       | 32.3           | 372.0        | 47.4 |

The analysis showed that the soil has low humus content, while mobile phosphorus and metabolic potassium have high content due to the introduction of optimal doses of mineral fertilizers.

When using the No-till technology the fertilizers were applied to the stable moist soil layer to ensure their good accessibility to plants. It was found that nutrients in the soil are washed away and displaced as a result of diffusion. The nitrogen fertilizers are washed mainly in the form of nitrates. This process usually occurs in early spring and late autumn, so it is important to choose the right time and method of...
applying the nitrogen fertilizers in order to bring it closer to the period of intensive assimilation of nitrogen by cultivated plants.

During the research period it was noted that the dynamics of productivity (40.7-49.8 kg/ha) was influenced by microorganisms that decompose plant residues of previous crops and the loss of active substance when granular nitrogen fertilizers are applied during feeding. At the same time, every year this technology is used, there are more and more microorganisms and their activity increases. The statistical analysis showed that the trend models of the relationship of technology and precursor to the agrochemical state of the soil and the yield of winter wheat have different binding strengths (d) and the proportion of variance of the dependent variable ($R^2$) (Table 5).

**Table 5.** Trend models of the relationship between the No-till technology and the precursor for the agrochemical state of the soil (0-20 cm) and winter wheat productivity (average for 2017-2019). *

| Parameters          | d      | $R^2$ | Different binding strengths | Regression equation      |
|---------------------|--------|-------|-----------------------------|--------------------------|
| pH                  | 0.645  | 0.428 | noticeable                  | Y = 209.7333 – 0.1$x_1$ |
| humus, %            | 1.0    | 1.0   | very high                   | Y = 2.72 – 0.01$x_1$     |
| N, mg/kg            | 0.866  | 0.75  | high                        | Y = 417.433 – 0.2$x_1$   |
| $P_2O_5$, mg/kg     | 0.50   | 0.25  | noticeable                  | Y = -1981.0 +1.0$x_1$    |
| $K_2O$, mg/kg       | 0.999  | 0.998 | very high                   | Y = 26636.3 – 13.0$x_1$  |
| Productivity, c/ha  | 0.98   | 0.97  | very high                   | Y = 2030.9 – 0.29071 $x_1$ |
| Humus, %            | 0.866  | 0.75  | very high                   | Y = 22.8 – 0.01$x_1$     |
| N, mg/kg            | 1.0    | 1.0   | very high                   | Y = 310.4 – 0.15$x_1$    |
| $P_2O_5$, mg/kg     | 0.944  | 0.893 | very high                   | Y = 517.9 – 0.25$x_1$    |
| $K_2O$, mg/kg       | 0.972  | 0.864 | moderate                    | Y = -874.87 + 0.45$x_1$  |
| Productivity, c/ha  | 0.99   | 0.99  | very high                   | Y =2032.81 -0.31722 $x_1$|

*d is the Pearson coefficient; $R^2$ is the coefficient of determination.

Based on statistical analysis it is necessary to control the content of available nutrients in the soil: nitrate nitrogen, mobile phosphorus, and metabolic potassium in order to stabilize the production capacity of winter wheat.

7. Conclusion
The research has shown that the cultivation of winter wheat without soil treatment (No-till) on dark chestnut soils in the arid zone from 2017 to 2019 does not lead to its compaction. The change in soil density was within the optimal values for the growth of winter wheat. An increase in soil density is associated with plant growth phases.

A positive effect is provided by the No-till moisture storage technology. The presence of plant residues on the soil surface ensures the accumulation and more economical expenditure of productive moisture in the soil. This allowed expanding the range of cultivated crops in the agricultural enterprise.

When applying the No-till technology much attention should be paid to the stabilization of the agrochemical properties of the soil and to the content of nitrate nitrogen. To obtain the sustainable winter crop yields, it is advisable to control the content of available nutrients in the soil and increase the dose of nitrogen fertilizers, depending on weather and climate conditions and the development of soil microorganisms. When sowing the crop, it is recommended that the farm add 100 kg of ammophos to increase its yield, which is higher than traditional technology.
References

[1] Deus A C F, Bull L T, Guppy C N, Santos S D C and Moreira L L Q 2020 Effects of lime and steel slag application on soil fertility and soybean yield under a no till-system Soil & tillage research 196 104422

[2] Dridiger V K, Kulintsev V V, Stukalov R S and Gadzhiumarov R G 2018 The dynamics of changes in the agrophysical properties of the soil when cultivating field crops using no-till technology News of the Orenburg State Agrarian University 5(73) 35-8

[3] Fiorini A, Maris S C, Abalos D, Amaducci S and Tabaglio V 2020 Combining no-till with rye (Secale cereale L.) cover crop mitigates nitrous oxide emissions without decreasing yield Soil & tillage research 196 104442

[4] Gromova N, Voskoboynikov A, Esaulko A, Sigida M and Lobankova O 2019 Influence of different methods of soil treatment and fertilizer systems on the yield of winter barley in the central Ciscaucasia IOP Conference Series: Earth and Environmental Science 315(5) 052025

[5] Nouwakpo S K, Song J and Gonzalez J M 2018 Soil structural stability assessment with the fluidized bed, aggregate stability, and rainfall simulation on long-term tillage and crop rotation systems Soil and Tillage Research 178 65-71

[6] Grechishkina Y I, Golosnoy E V, Esaulko A N, Sigida M S and Ozheredova A Y 2019 Influence of cultivation technologies of agricultural crops with the use of machines and tools of domestic and foreign production for the dry area of the South of Russia IOP Conference Series: Earth and Environmental Science 315(5) 052030

[7] Dridiger V K 2016 Mistakes in mastering no-till technology Agriculture 3 5-9

[8] Dridiger V K 2018 No-till technology and mistakes made during its development Agricultural Journal 1(1) 14-23

[9] Dridiger V, Nevecherya A, Taran G and Shapovalova N 2017 Ipatov experience in cultivating field cultivators without tillage (no-till) AgroSnabForum 3(151) 35-40

[10] Sarker J R, Singh B P, Cowie A L, Badgery W and Dalal R C 2018 Agricultural management practices impacted carbon and nutrient concentrations in soil aggregates, with minimal influence on aggregate stability and total carbon and nutrient stocks in contrasting soils Soil and Tillage Research 178 209-23

[11] Sun M, Huo Z, Zheng Y, Feng S and Mao X 2018 Quantifying long-term responses of crop yield and nitrate leaching in an intensive farmland using agro-eco-environmental model Science of the Total Environment 1003-12

[12] Pismennaya E, Stukalo V, Volters I, Kipa L and Azarova M 2019 Animal husbandry of south of Russia: Current state and prospects of development Engineering for Rural Development 18 337-42

[13] Schlegel A J, Assefa Y, Haag L A, Thompson C R and Stone L R 2019 Soil Water and Water Use in Long-Term Dryland Crop Rotations Agronomy journal 111 2590-9

[14] Wang J and Zou J 2020 No-till increases soil denitrification via its positive effects on the activity and abundance of the denitrifying community Soil Biology and Biochemistry 142 107706

[15] Pismennaya E V, Volters I A, Azarova M Yu and Stukalo V A 2019 The organization of the territory of agricultural land use in the South of Russia on an environmental-landscape basis (using the example of an agricultural enterprise) IOP Conference Series: Earth and Environmental Science 315 052032