Influence of the main tillage methods on the moisture temperature mode of the soil and the yield of winter wheat

Yulia Semenikhina¹, Sergey Kambulov¹, Andrey Boyko², Yury Nadolinsky² and Dmitriy Podlesniy²

¹State Scientific Establishment “Agricultural Research Center "Donskoy", 14, Zernograd, Lenin st., Russian Federation
²Federal State Budgetary Educational Institution of Higher Education "Don State Technical University", 1, Gagarin Square, Rostov-on-Don, Russian Federation

E-mail: semenixina1982@mail.ru

Abstract. The accumulation and preservation of soil moisture through rational tillage methods is an effective strategy for increasing the yield of winter wheat in the zone of risky farming with insufficient and unstable moisture. The article discusses the methods of tillage: surface, shallow, moldboard and no-Till. Their influence on the moisture-temperature mode of the soil is investigated. Weather and climatic conditions was taken into account. Correlation analysis identified an average negative interdependence between soil moisture and ambient (atmospheric) air humidity and a high positive relationship between soil temperature and ambient air temperature. The yield of winter wheat for the study period analyzed depending on the applied method of tillage. The leading position of no-Till tillage in terms of the yield of winter wheat (7.17 t / ha), as well as in the moisture-temperature mode was revealed. At the same time, with shallow tillage, moisture was recorded at 20.12%; 17.75% with surface tillage; by 13.19% using the moldboard method. Warming up of the soil was established with shallow tillage by 12.19%; with a dump method by 13.19%; with the surface method by 4.12%. A decrease in the yield of winter wheat was revealed with the moldboard method by 8.37%; with the surface method by 8.37%; with a zero method by 12.14%. It has been established that no-Till tillage is the most effective in terms of maintaining soil moisture and yield of winter wheat in the zone of risky farming.

1. Introduction

Any technology for the cultivation of agricultural crops is based on soil, weather and climatic conditions [1], corresponding to the geographical location. The southern regions of Russia are characterized by unstable and insufficient moisture, frequent periods of droughts and progressive soil degradation, which is facilitated by wind and water erosion. Under such conditions, any farming becomes risky [2-3]. In this case, intensive moldboard tillage [4] of the soil with simplified crop rotation is detrimental to the arable fertile layer and can lead to a decrease in the yield of winter wheat. According to scientists [5], combined and minimal cultivation methods with the operation of layer-by-layer loosening, contributing to the preservation of plant residues from stubble, have a sparing effect on the soil layer, while providing an optimal soil structure [6-7]. As a result, favorable conditions are formed for biological, chemical, physical and other processes. Decomposition of the soil occurs, as well as protection of the fertile layer from weathering and leaching. It becomes possible to accumulate and retain soil moisture [8-9]. In connection with the above, the goal of research was determined - to
establish the effect of soil cultivation methods on the moisture-temperature regime of the soil and the yield of winter wheat for the zone of risky agriculture with insufficient and unstable moisture.

2. Materials and methods

The research was carried out based on many years of stationary experience. Data received in 2017-2019. The cultivated crop is winter wheat. The soil of the experimental site is characterized by ordinary carbonate heavy loamy chernozem. Content of humus in the arable layer of soil: - 3.4%; pH - 7.2; P2O5 - 19.5-24.2 mg / kg; K2O - 320-332 mg / kg of soil. Observation of weather conditions during the growing season of winter wheat showed their difference, both for precipitation and in air temperature. For the 2016/2017 agricultural year, the amount of precipitation and the average daily air temperature were 126% and 114% higher than the average annual ones, respectively. During the 2017/2018 agricultural year, an uneven seasonal precipitation was recorded, their sum was 103% of the norm, and the average monthly air temperature was higher than the average annual (by 118%). In the 2018/2019 agricultural year, there was a slight excess of precipitation (108% of the long-term norm) and an increased temperature regime of the air during the growing season (129% of the norm).

We have studied the following methods of soil cultivation [10-11], which form the basis of the traditional mechanized technology of cultivation of agricultural crops. The method of surface loosening of the soil was carried out with disc batteries to a depth of 8-10 cm. The method of shallow loosening was carried out by a combined tillage unit, which combines the operations of loosening, crumbling blocks, combing out weeds and subsequent compaction of the soil to a depth of 12-14 cm. Method of loosening by means of moldboard plowing a plow with a turnover of the soil layer to a depth of 23-25 cm. The no-till method consisted of a single impact on the soil and only during the sowing period. Also, this method of soil cultivation has a field mulching layer of plant residues from previous crops, which prevents evaporation and overheating of the soil. The last method refers to the zero technology (No Till) of winter wheat cultivation [12].

To determine soil moisture and temperature directly in the field, we used Watch Dog 1400 Micro meteorological stations (recorders) from Spectrum Technologies, Inc. (USA), equipped with sensors for measuring soil moisture and temperature, which were placed in the soil according to the scheme shown in figure 1. Meteorological stations were set up using the Spec Ware 9 Basic program to record moisture and temperature indicators at intervals of one hour (24 measurements per day).

Meteorological stations were placed in a waterproof case. Moisture and temperature sensors were immersed in a 30 cm soil layer in experimental field plots. The soil of the plots was cultivated in various ways, which are part of the technology for the cultivation of winter wheat. The range of measured values of relative humidity is 0-100% with an error of ±3%.

Figure 1. Layout of a weather station (recorder) in the studied soil layer. Watch Dog series 1400 Micro, humidity and temperature sensors.
The range of measured temperatures is 40-85 °C with an error of ± 0.6 °C. Data retrieval from the internal memory of weather stations took place monthly on a laptop. Simultaneously with these studies, the humidity and temperature of the ambient (atmospheric) air, as well as the amount of precipitation during the observation period, were recorded.

3. Results

As a result of studying the dynamics of soil moisture and temperature from 24 indicators, their average daily values were calculated. After revealing the dependence of soil moisture and temperature on various methods of its processing, their comparative assessment was carried out taking into account atmospheric conditions: humidity and ambient temperature, the amount of precipitation. The results of studies of the dynamics of soil moisture and temperature are presented in tables 1 and 2.

Table 1. The results of the study of soil moisture by years, depending on the methods of basic soil cultivation at a depth of 30 cm, %.

| Tillage method         | 2017   | 2018   | 2019   | Average, % | Change to average, % |
|------------------------|--------|--------|--------|------------|----------------------|
| Surface processing     | 44.78  | 43.41  | 41.4   | 43.20      | 82.25                |
| Shallow processing     | 43.12  | 42.84  | 39.90  | 41.95      | 79.88                |
| Moldboard processing   | 47.62  | 47.56  | 41.60  | 45.59      | 86.81                |
| No-Till processing     | 58.71  | 52.35  | 46.50  | 52.52      | 100.00               |

When analyzing the results (table 1) of studies of the soil moisture regime, the soil with zero tillage (100%) of winter wheat cultivation was taken as the "standard" of the preserved soil. The influence of other methods of tillage on the soil moisture regime was manifested as follows: with shallow and superficial methods of tillage, the loss of soil moisture was maximum and amounted to 20.12% and 17.75%, respectively; with a moldboard processing method by 13.19%.

Statistical processing of the data established an average negative correlation between the humidity of the ambient air and the moisture content of the soil during surface treatment $r = -0.42$; with fine processing $r = -0.48$; with zero processing, $r = -0.42$; during moldboard processing, there is practically no correlation $r = -0.15$.

Thermal processes in the soil proceeded similarly to the soil moisture regime. The results of this study are presented in table 2.

Table 2. The results of the study of soil temperatures by years depending on the methods of the main tillage at a depth of 30 cm, °C.

| Tillage method         | 2017   | 2018   | 2019   | Average, °C | Change to Average, % |
|------------------------|--------|--------|--------|-------------|----------------------|
| Surface processing     | 10.62  | 12.64  | 7.84   | 10.37       | 104.12               |
| Shallow processing     | 12.32  | 13.12  | 8.07   | 11.17       | 112.19               |
| Moldboard processing   | 11.71  | 13.46  | 8.13   | 11.10       | 111.48               |
| No-Till processing     | 9.76   | 12.30  | 7.81   | 9.96        | 100.00               |

As a result of studies of the soil temperature regime, it was revealed that with zero tillage, the soil was less heated and for further comparison was taken as a basis (100%). Thus, the influence of other methods of soil cultivation on the temperature regime of the soil revealed the following: with shallow and dump methods of cultivation, the average warming up of the soil was maximum and amounted to 12.19 °C and 11.48%, respectively; with the surface method, heating was insignificant, and amounted to 4.12%.
Statistical processing established a direct close correlation between soil temperature and air temperature during surface treatment $r = 0.96$; with fine processing $r = 0.95$; with moldboard processing $r = 0.93$; at zero processing $r = 0.95$.

Studies on the yield of winter wheat for three years are presented in table 3. It follows that 2017 as a whole has a high yield in comparison with other years of research, which is explained by favorable weather conditions this year.

| Table 3. Results of the study of the yield of winter wheat by years depending on the methods of the main tillage, t / ha. |
| Tillage method          | 2017  | 2018  | 2019  | Average, t / ha | Change to Average, % |
|-------------------------|-------|-------|-------|-----------------|----------------------|
| Surface finish          | 8.63  | 5.43  | 5.64  | 6.57            | 91.63                |
| Fine processing         | 7.23  | 5.63  | 6.05  | 6.30            | 87.86                |
| Moldboard processing    | 7.70  | 6.23  | 6.41  | 6.78            | 94.56                |
| Zero processing         | 8.48  | 6.27  | 6.75  | 7.17            | 100.00               |

The general analysis of the data obtained showed that, on average, over the years of research, the tendency of high yield was recorded with no tillage. With respect to this method, a decrease in yield by 12.14% was revealed with shallow tillage; by 8.37% with surface tillage; by 5.44% with moldboard tillage.

4. Discussion

The study of soil moisture and the data obtained in the course of its study indicates that stable moisture conservation is ensured by zero processing, which is explained by the presence of a mulching layer and the principle of non-interference with the soil structure, which allows self-organizing biochemical, physiological and other soil processes, seeking to reduce them to balance. At the same time, the correlation analysis confirms that the smallest interference in the structure of the soil during its processing (surface, shallow, zero tillage) have similar patterns in the course of migration processes of soil moisture depending on the humidity of the surrounding air.

The study of the temperature regime of the soil has established that the method of soil cultivation and the presence of a mulch layer affect the temperature of the soil. In addition, the thermal inertness of the soil itself with the emerging temperature difference is capable of creating a dew point, contributing to the appearance of additional conditioned moisture, which is important in the absence of precipitation and high air temperatures.

A study on winter wheat yields revealed the advantage of zero-till, both on average and for each year under study.

5. Conclusion

Thus, the leading position in terms of the moisture-temperature regime of the soil and the yield of winter wheat was fixed on no-Till tillage. Comparison of various methods of processing relatively no-Till revealed that with surface processing, soil moisture is reduced by 17.75%, the temperature of the soil is warmed up by 4.12%, and the yield is reduced by 8.37%. With shallow tillage, soil moisture is reduced by 20.12%, soil temperature is warmed up by 12.19%, and yield is reduced by 12.14%. With the dumping method, soil moisture is reduced by 13.19%, the soil temperature is warmed up by 11.48%, and the yield is reduced by 5.44%. Consequently, the use of zero tillage in the zone of risky agriculture with insufficient and unstable moisture is highly effective.

References

[1] Zhichkin K, Nosov V, Zhichkina L, Zhenzhebir V and Rubtsova S 2020 The agricultural crops production profitability in modern conditions. E3S Web of Conferences 2048 13008
[2] Kassam A and Coates D 2019 The Global Uptake of Conservation Agriculture and the Impact
on Water-Related Ecosystem Services *The Oxford Handbook of Food, Water and Society* New York 690-708

[3] Kassam A, Friedrich T, Shaxson F and Pretty J 2009 The spread of conservation agriculture: Justification, sustainability and uptake. *International Journal of Agricultural Sustainability* 7 292-320

[4] Kribaa M, Hallaire V, Curmi P and Lahmar R 2001 Effect of various cultivation methods on the structure and hydraulic properties of a soil in a semi-arid climate. *Soil and Tillage Research* 60 43-53

[5] Shekhar A and Shapiro C A 2019 What do meteorological indices tell us about a long-term tillage study? *Soil and Tillage Research* 193 161-170

[6] Semenikhina Yu A, Kambulov S I, Parkhomenko G G, Boyko A A, Ponomareva S V , Shvedova S V, Kolisov A F and Tsybenko E O 2020 Methods of tilling under conditions of insufficient and unstable moistening during winter wheat cultivation. *E3S Web of Conferences* 175 09008

[7] Parkhomenko G G, Kambulov S I, Olshevskaya A V, Babadzhanyan A S, Gucheva N V and Mekhantseva I Y 2019 The tillage effect on the change of soil structure. *IOP Conference Series: Earth and Environmental Science* 455 012144

[8] Kool D, Tong B, Tian Z, Heitman J L, Sauer T J and Horton R 2019 Soil water retention and hydraulic conductivity dynamics following tillage. *Soil and Tillage Research* 193 95-100

[9] Pandey V and Pandey P K 2010 Spatial and Temporal Variability of Soil Moisture. *International Journal of Geosciences* 1 87-98

[10] Hijbeek R van Ittersum M K ten Berge H F M, Gort G, Spiegel H, and Whitmore A P 2017 Do organic inputs matter – A metaanalysis of additional yield effects for arable crops in Europe. *Plant and Soil* 411 293–303

[11] Denardin J E, Kochhann R A, Faganello A, Sattler A and Manhago D D 2008 “Vertical mulching” como pratica conservacionista para manejo de enxurrada em sistema plantio direto. *Revista Brasileira de Ciencia do Solo* 32 2847-2852

[12] Telles T S, Righetto A J, Lourenco M A P, and Barbosa G M C 2020 No-tillage system participatory quality index. *Revista Brasileira de Engenharia Agrícola e Ambiental* 24 128–133