Some parameters of the agrochernozems physical and water-
physical properties under field crops cultivation in drought
conditions

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Abstract. Studies have established that in a layer of 0-20 cm, the density of soil compaction in all fields of crop rotation was characterized as loose (0.83-0.97 g / cm³), while the humus content was medium and high (5.6 - 7.8%). During the drought, an increase in the density of addition was found to be 1.4-1.1 times in all fields of crop rotation, with the exception of pure steam. Reserves of productive moisture were unsatisfactory and amounted to 10.2 for potato cultivation, soy, and wheat - 14.3 and 15.8 mm, respectively, net fallow land had significantly higher reserves of productive moisture, which amounted to 19.7 mm. After harvesting in September, productive moisture reserves in the 0–20 cm layer reached satisfactory values of 25.8–36.9 mm; the maximum reserve was formed in pure fallow land and during the cultivation of wheat.

1. Introduction

The chernozems of the forest-steppe zone of the Krasnoyarsk Territory are formed in a continental and moderately dry climate, rainfall is extremely uneven, which leads to alternating periods of severe desiccation of the soil and its abundant wetting [1]. Under such conditions, the physical and water-
physical properties of soils, such as the density of addition and reserves of productive moisture, are one of the main parameters of the fertility of agrochernozems in the forest-steppe zone that determine the yield of most crops [2]. The water reserves in the soil primarily depend on the amount of precipitation, as well as on its particle size distribution and humus content [3]. The density of addition of the arable layer of agricultural soils is determined to a greater extent by the action of treatment [4, 5]. In extremely dry periods, the physical parameters of soils can vary significantly [6] and, therefore, the aim of our research is to study the main parameters of the physical and water-physical properties of the arable layer of agrochernozems when using elements of soil protection technologies in the units of grain-crop rotation in the Krasnoyarsk forest-steppe during drought.

2. Objects, conditions and methods

The studies were conducted in 2018 on the territory of the Krasnoyarsk forest-steppe at the LSPC "Borsky" of the Krasnoyarsk State Agrarian University (Krasnoyarsk SAU). As an object of research, the links of crop rotation were selected: steam - potato - soybean - spring wheat. The crop rotation was laid in 2017 by the Department of Plant Growing, Breeding and Seed Production of the Krasnoyarsk SAU. Soils: a complex of agrochernozems of typical clay-illuvial and agrochernozems of cryogenic-
mycelial medium and heavy loamy varieties. Before setting up the experiment, the soils had a high and extremely high amount of exchange bases in the humus horizon (35 - 56 mg-eq / 100 g), slightly acidic,
neutral, and slightly alkaline soil solution, increasing with depth (pH \( \text{Н}_2\text{О} \) 6.5-7.8). The humus content varied from medium to high (5.8 - 6.9%).

Potatoes of super-elite of Aramis variety (precursor - pure steam), soya of super-elite of Zaryanitsa variety (precursor - potato), spring wheat of variety Novosibirsk 15 (precursor - soy) were cultivated for seed purposes. Fertilizers were not applied; plant protection products were used. Elements of soil protection technologies were flat cutting and stubble leaving during soy and wheat cultivation, desiccation, chopping and scattering of potato tops. Preparation of pure steam was carried out according to classical technology and consisted of autumn plowing to a depth of 25–27 cm and four cultivations during the growing season to a depth of 8–10 cm. Mixed soil samples were taken in June, July, August and September, after harvesting. The sampling was 4-fold, the sampling depth was 0–20 cm. In soil samples, the moisture was determined by the thermoweight method, the Kachinsky addition density, and the humus content by the Tyurin method [7]. The results were processed using descriptive statistics and analysis of variance.

The vegetation period of 2018 was quite extreme in terms of hydrothermal conditions (table 1). An analysis of meteorological data [8] showed that the sum of active temperatures was 1897.7 °C with an average long-term value for a given area of 18000 °C, and the amount of precipitation was lower by an average of 13.4%, compared with the long-term average. The hydrothermal coefficient under farm conditions during the observation period in 2018 varied from 2.13 to 0.11, and averaged 0.77 from May to August, with a norm of 1.3 - 1.4.

Table 1. Hydrothermal conditions of the vegetation period 2018 (according to the data of the Sukhobuzimskaya weather station, Krasnoyarsk Territory).

| Months  | Air temperature, °C | Precipitation, mm | Hydrothermal index |
|---------|---------------------|-------------------|-------------------|
| 2018    |                     |                   |                   |
| May     | 8.1                 | 29.00             | 2.13              |
| June    | 20.6                | 28.60             | 0.46              |
| July    | 18.5                | 6.50              | 0.11              |
| August  | 18.4                | 20.70             | 0.36              |
| September | 10.0               | 55.30             | 2.13              |

Degree days = 1897.7 °C

Long-term average

| Months | Air temperature, °C | Precipitation, mm | Hydrothermal index |
|--------|---------------------|-------------------|-------------------|
| May    | 10.0                | 32.0              | 1.38              |
| June   | 16.4                | 44.0              | 1.27              |
| July   | 18.9                | 69.0              | 1.28              |
| August | 14.2                | 62.0              | 1.34              |

Effective heat sum \( p = 1800 \) °C

Thus, the growing season of observations in 2018 was warmer and drier than the long-term average and was distinguished by a combination of extremely dry (July) and extremely wet periods (May and September).

3. Results and discussion

The humus content in soils ensures its stable functioning in time and space, while maintaining the stability of properties and conditions even under extreme conditions and at high agrogenic loads [9]. Humic substances not only serve as a food source for heterotrophic microorganisms, stimulate soil biological activity and mineralization processes, as a result of which nutrients for plants are released, they also participate in the structure formation and formation of water-physical properties of the soil, supporting its effective fertility [10]. In our studies, agrochernozems were characterized by medium and high (5.6–7.8%) humus content in the 0–20 cm layer (table 2). The spatial variation of the humus content was medium (CV = 14.3 - 24.9%). Such variability of the humus content, even within small
areas, is characteristic of agrocheronozemes of the forest-steppe zone of Siberia. This is explained by the diversity of the soil cover and parent rocks, heterogeneity of the microrelief, and different thicknesses of the humus horizon [11]. Thus, as a result of spatial heterogeneity, the soil in the potato field turned out to be more humored in comparison with other fields of crop rotation.

Table 2. Humus content in the fields of grain and crop rotation, %.

| Crop rotation link                  | Statistical Parameters |
|-------------------------------------|------------------------|
|                                     | X (n=40) | Sx  | min | max | Cv, % |
| Fallow (control)                    | 6.01     | 0.52 | 4.11 | 7.88 | 24.9  |
| Potato                              | 7.83*    | 0.40 | 6.27 | 9.25 | 15.2  |
| Soya                                | 6.05     | 0.36 | 4.05 | 7.72 | 18.0  |
| Spring wheat                        | 5.56     | 0.27 | 4.29 | 6.56 | 14.3  |

HCP 0.5 = 1.80 %

The average density of soil compaction in the crop rotation fields was 0.83-0.97 g/cm³ and was estimated as loose (table 3).

Table 3. Dynamics of moisture (%) and density of addition (g/cm³) of soil in a layer of 0-20 cm

| Selection period | Field moisture, % | Wilting moisture (WM), % | Bulk density, g/cm³ |
|------------------|-------------------|--------------------------|---------------------|
|                  | soybean (precursor - potato) |                         |                     |
| June             | 22.40             | 14.45                    | 0.79                |
| July             | 16.72             | 13.45                    | 0.80                |
| August           | 18.62             | 14.40                    | 1.10                |
| September        | 32.93             | 12.59                    | 0.74                |
| X                | 22.67             | 13.72                    | 0.86                |
| Sx               | 7.24              | 0.88                     | 0.16                |
| Cv, %            | 31.93             | 6.44                     | 19.10               |
|                  | potato (precursor – complete fallow) |                       |                     |
| June             | 21.28             | 13.78                    | 0.72                |
| July             | 14.44             | 13.42                    | 1.29                |
| August           | 15.72             | 14.99                    | 1.16                |
| September        | 32.50             | 14.31                    | 0.71                |
| X                | 20.99*            | 14.13                    | 0.97*               |
| Sx               | 8.23              | 0.68                     | 0.30                |
| Cv, %            | 39.22             | 4.82                     | 30.85               |
|                  | complete fallow (precursor – wheat) |                   |                     |
| June             | 23.11             | 14.57                    | 0.96                |
| July             | 23.39             | 14.80                    | 0.62                |
| August           | 24.15             | 13.02                    | 0.70                |
| September        | 38.65             | 13.86                    | 0.73                |
| X                | 27.33             | 14.06                    | 0.83                |
| Sx               | 7.56              | 0.80                     | 0.21                |
| Cv, %            | 27.68             | 5.72                     | 25.33               |
|                  | spring wheat (precursor – soybean) |                       |                     |
June  |  21.76  |  12.72  |  0.80  
July   |  16.25  |  12.37  |  0.80  
August |  15.74  |  13.00  |  1.00  
September |  35.66  |  12.86  |  0.81  
X       |  22.35  |  12.74  |  0.85  
Sx      |  9.28   |  0.27   |  0.10  
CV, %   |  41.52  |  2.12   |  11.55 
HCP, 0.5 |  4.06   |  3.76   |  0.093 

X - average, Sx - standard deviation, CV, % - coefficient of variation, * - significant differences relative to complete fallow

A significant decrease in the density of addition to 0.62 g / cm³ was observed in the fallow field in July due to cultivations. When cultivating potatoes, the average addition density increased to 0.97 g / cm³, which is explained by the presence of compacted addition between manes (1.31 - 1.27 g / cm³) and loose addition in manes (0.61 - 0.82 g / cm³). When soybean and spring wheat are cultivated against the background of flat-cutting processing, the dynamics of addition density is similar, it gradually increases by August to 1.0 - 1.1 g / cm³ and decreases after harvesting in September to 0.74 - 0.81 g / cm³.

In addition, it was found that in all crop rotation fields, with the exception of fallow, its density increases significantly with decreasing soil moisture (figure 1), the relationship between soil moisture and addition density is well approximated by a second degree polynomial (r = 0.73).

![Figure 1. Dependence of humidity (%) and soil density (g / cm³) in a layer of 0-20 cm.](image)

In June, soil moisture in the layer of 0-20 cm in all parts of the crop rotation was at the level of 21 - 23%, while the WL for these agrochernozems averaged 13-14%. The reserves of productive moisture at that time in the fields of all links of the crop rotation were not satisfactory, the moisture reserves were especially low in the potato field - 10.8 mm (figure 2).
Figure 2. Reserves of productive moisture in the soil layer 0-20 cm, mm.

A similar dependence was obtained for soils of the steppe zone of L.M. Tatarintsev [12], the author noted that for heavy loamy soils, the greatest increase in density is observed with a decrease in soil moisture in the range from capillary rupture humidity (CRH) to wilting moisture (WM), this moistening interval corresponds to the stages of normal and residual soil shrinkage. With further drying of the soil, due to the lack of shrinkage, its density does not change. With an increase in humidity in the range from the minimum moisture capacity (MM) to the CRH, corresponding to the stage of structural shrinkage, density change also practically does not occur. Thus, in the studied agro-chernozems, in the arid conditions of 2018, when the soil moisture was approaching the wilting moisture, shrinkage occurred along the border of the peds, which led to an increase in the density of soil compilation. In the fallow field, such a pattern is not observed, here the soil moisture even in the driest period was at the level of 23-24%, and the density of addition decreased after the treatments.

Perhaps this is due to the fact that in the ridges cut for planting potatoes, the soil warmed up and dried out faster than on flat areas of arable land [13]. Further in July, extremely arid conditions were observed, the HTC decreased to 0.11, which led to a sharp decrease in productive moisture reserves in the soil, especially against the background of increased crop water consumption. At this time, when cultivating potatoes, the reserves of productive moisture fell to their minimum values (2.3-2.6 mm). In August, the amount of precipitation increased, but the air temperature was quite high, the HTC amounted to 0.36, the reserves of productive moisture in the field of potatoes and wheat continued to decrease, in the fallow field and during the cultivation of soybeans increased to 15.6 and 9.3 mm, respectively. This is explained by the moisture-accumulating role of complete fallow [14] when soil cultivation prevents physical evaporation of moisture and the shading effect of soy. In September, after harvesting, the amount of precipitation increased significantly, the HTC amounted to 2.13, while the reserves of productive moisture in the 0-20 cm layer reached satisfactory values of 25.8-36.9 mm, the maximum reserve was formed in complete fallows and during cultivation wheat. On average, during the growing season, under extremely arid conditions, complete fallows had significantly higher reserves of productive moisture, which amounted to 19.7 mm. When cultivating potatoes, they were 10.2, while cultivating soy and wheat - 14.3 and 15.8 mm, respectively.
4. Conclusion
In the often-repeated arid conditions on the territory of the Krasnoyarsk forest-steppe, fallow fields are of particular importance for preserving and maintaining the optimal physical and water-physical properties of soils. Loosening and cultivation of fallow fields contribute to the accumulation of moisture and softening of soils, even in extremely dry periods. At the same time, the full return of crop remains and the positive balance of plant matter in the studied agrochernozems [15] ensures a stable humus content in time and space and prevents its excessive mineralization during evaporation.

References
[1] Krupkin P I 2009 Soil cover - the basis of natural zoning and agricultural use of the geomorphologically complex territory of the agricultural part of the Krasnoyarsk Territory The Bulletin of KrasSAU 6 23–33
[2] Egunova N A, Zagorodnaya E A and Potylitsyn R G 2013 Soil and climatic indicators and productivity of grain crops in the forest-steppe zone of the south of the Krasnoyarsk Territory The Bulletin of KrasSAU 10 78-82
[3] Tanasienko A A, Chumbaev A S and Yakutina O P 2019 The Impact of Climatic Humidity of the Southeastern Part of Western Siberia on Spring Deficit of Moisture in the Profiles of Eroded Chernozems Eurasian Soil Science 52(8) 935–44
[4] Eremin D I and Moiseev A N 2012 Effect of crop rotation on the physical properties of leached chernozem Siberian Herald of Agricultural Science 6 26–32
[5] Solodovnikov A P, Denisov K E, Danilov A N, Korsak V V and Pimonov K I 2018 Minimizing tillage to preserve the agro-chemical and water-physical properties of southern black soil after vegetative reclamation International Journal of Mechanical Engineering and Technology 9 (12) 1166–72
[6] Mitrofanov D V, Maksyutov N A, Skorokhodov V Yu, Kaftan Yu V and Zenkova N A 2017 The effect of productive moisture on crop yields in arid conditions of the Orenburg region The Herald of Beef Cattle Breeding 4(100) 225-33
[7] Agrochemical methods of soil research 1975 ed A V Sokolov (Moscow: Nauka)
[8] Website of rp5.ru Reliable Prognosis LLC Retrieved from: http://rp5.ru/Weather_in_Suhobuzimsky
[9] Kiryushin V I 2019 The Management of Soil Fertility and Productivity of Agrocenoses in Adaptive-Landscape Farming Systems Eurasian Soil Science 52(9) 1137–45
[10] Semenov V M and Kogut B M 2015 Soil organic matter (Moscow: GEOS)
[11] Bugakov P S, Gorbacheva S M and Chuprova V V 1981 Soils of the Krasnoyarsk Territory (Krasnoyarsk: Krasnoyarsk Book Publishing House)
[12] Tatarintsev L M 2005 Natural dynamics of the physical and thermophysical properties of soils Bulletin of Altai State Agricultural University 3(19) 36-41
[13] Xu Cheng Zhang, Jun Guo, Yi Fan Ma, Xian Feng Yu, Hui Zhi Hou, Hong Li Wang, Yan Jie, Fang Ying and Fang Tang 2020 Effects of vertical rotary subsoiling with plastic mulching on soil water availability and potato yield on a semiarid Loess plateau, China Soil and Tillage Research 199 104591 Retrieved from: https://doi.org/10.1016/j.still.2020.104591
[14] Berzin A M and Polosina V A 2018 Increasing the efficiency of pure and green manure fumes in the forest-steppe and steppe regions of Siberia Bulletin of KrasSAU 3 39–44
[15] Vlasenko O A, Khalipsky A N and Stupnitsky D N 2019 Vegetable structure balance in agrochernozems and the quality of seed production in the field crops cultivation with elements of soil protective technologies IOP Conference Series: Earth and Environmental Science 315(4) 052045