Influence of treatments on the physical and chemical properties of the soil in the Dry-Steppe zone of the Lower Volga region

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Abstract
The assessment of the influence of soil cultivation on the accumulation of NPK in fallow fields is given on light chestnut soils in the Volgograd region. Changes in the nutrient regime of the soil under the influence of various weather conditions of the year are revealed. It was found that the higher content of nutrients in steam fields is mainly due to non-fallow tillage, in some years, which has optimal moisture supply, and the control (dump) option in comparison with lower indicators for surface treatment in all years of research. The main comparison in the change of nutrients in steam fields is observed for different methods of tillage. For comparison, the article presents the results on the accumulation of NPK processed by the direct sowing system, i.e. NO-TILL without the intervention of mechanical tillage.

Key words: tillage; structural and aggregate composition of soil; food regime; grain crops

INTRODUCTION

In the conditions of priority development of adaptive landscape farming systems, it is of great importance to improve soil treatment systems, their differentiation depending on landscape conditions, soil types and their properties, the choice of cultivated crops, biologization techniques that are used, etc. (Kashtanov, 2008). Proper processing that corresponds to soil and climatic conditions is an important means of regulating the agrophysical state of the soil, its biological properties, nutrient and water regimes, humus content and reserves, crop yield and product quality (Suxov et al., 2007; Suxov, 2011; Lentochkin et al., 2016).

Attempts to use foreign technologies that are not adapted to the specific natural and soil conditions of various regions of the Russian Federation lead to a decrease in their effectiveness.

A comprehensive analysis of the problem of resource conservation and, above all, in the system of tillage indicates the need for deep research in this direction, which should be based on the principles of adapting techniques and methods to the natural features of the region and rational use of energy resources. Together such technologies should ensure sustainable production of agricultural products, eliminate the decline in soil fertility and the deterioration of the environmental situation caused by the processes of erosion, deflation and loss of energy resources of the soil (Loshakov, 2012; Tagirov et al., 2015). The study of the most economically and ecologically effective methods of minimizing the main tillage during long-term and short-term use in crop rotations with grain crops in the soil and climatic conditions of light chestnut soils of the Lower Volga region (Azizov, 2004; Belyakov & Solonkin, 2012; Klopperancz, 2007; Smirnov, 1973) is of particular relevance in modern economic conditions of management.

MATERIALS AND METHODS

The experiment is being carried out on the experimental plot of the Lower Volga Research Institute of Agriculture in the conditions of semi-desert plain agricultural landscapes of light chestnut soils (Haplic Kastanozems 13-1).

A) The site is located in the system of a hollow drainage basin on the slope of the western exposure with a slope of up to 2°C. The soil of the experimental site is light chestnut with a humus content in the arable layer of 1.74%, total nitrogen and phosphorus of 0.12% and 0.11%, respectively.

According to the Kachinsky classification, the soil is silt-heavy loam according to its mechanical composition: physical sand contains 49.3% and physical clay 50.7%). The reaction of the soil solution in the arable layer is pH-8.1. Soils are alkaline in their composition.

The object of research is a 4-field crop rotation (factor A), options for basic soil cultivation (factor B) and sowing with a Don-114 seeder (seeder for direct sowing) superimposed on soil cultivation options. Placement of options (A) sequential and options (B) in blocks in three tiers. The main tillage is carried out with the following tools: dump to a depth of 25-27 cm with a plow PN-4-35, non-dump to a depth of 25-27 cm with a tool OCHO-5-40 with a rack "ranch", (Pleskachev & Borisenko, 2012) surface to a depth of 8-10 cm with a tool BDM-4.2, as well as 4-pole grain-steam crop rotation, which includes the following crops: black-winter wheat-safflower-barley steam, sowing of crops, produced by the Don-114 seeder).

Б). The 4-hectare plot will be used directly for direct seeding. The crop rotation will be similar to that of the main crops (chemical steam-winter wheat-safflower-barley).

Research on NO-TILL technology, where cultures are grown without the treatment, selection of crops and their alternation in crop rotation has its own characteristics, as maintaining high agrophysical properties of the soil, including tillage, occurs to the root systems of cultivated plants. Therefore, in the crop rotation, plants with fibrous and tap root systems should be alternated. The fibrous root system penetrates with its numerous roots the upper, most fertile layer of the soil, thereby providing high structure, water permeability and optimal body density. Taproot cultures provide loosening of deeper soil layers so that moisture from atmospheric precipitation can penetrate and accumulate in deeper soil layers (Dospexov, 1985; Klopperancz, 2007; Kulincev & Dridiger, 2014).

Also, an equally important requirement is the inclusion of plants in the crop rotation that leave as much plant residues as possible on the soil surface, which reliably protect the soil from wind and water erosion, and also ensure the accumulation and preservation of soil moisture.

The works proposed using this technology include: pre-sowing application of herbicides (glyphosates 10-14 days before sowing), crop sowing, crop harvesting, and cover crop sowing. Records and observations are carried out according to the recommendations on the method of conducting observations and research in the field experience (Saratov, research Institute of the South-East, 1973), the method of experimental work, B. A. Dospekhov (Dospexov, 1985). Features of scientific research on the technology of cultivation of agricultural crops without tillage (No-till), V. I. Kiryushin, and V. K. Dridiger (Kulincev & Dridiger, 2014). Water-physical: moisture content by weight % and density in g/cm^3 - by Kaczynski's weight method._The density of the soil is determined by the bulk density in the 0-30 cm layer, every 10 cm. By the method of cutting rings. Samples are taken in four-fold repetition on all variants of the main treatment of the control and the studied four-field crop rotation without treatments at the time: black fallow - in the spring after the moisture closure and before sowing winter wheat. In winter wheat crops - after closing moisture in spring and before harvesting. The aggregate composition of the soil (according to the method of N. I. Savinov, 1931, modified by the TSKhA) is made according to the average sample taken from 10 pits, one repetition at each variant of the main soil cultivation of the control and the studied four-field crop rotation without treatments in time: for black fallow - after closing moisture after sowing winter wheat. In winter wheat crops after harrowing and before harvesting. Nutrient regime of the soil: a) the content of nitrates, nitrate nitrogen by the disulfenol method, and ammonia nitrogen by the colorimetric method; b) mobile phosphorus (P_2O_5) according to Chirikov's method; c) exchangeable potassium (K_2O) - flame photometric.

RESULTS AND DISCUSSION

During basic treatments, the top layer of soil is more dispersed and moves down, while the lower layer, which is more structured, will rise to the surface. It is exposed to the mechanical effects of tillage tools during soil preparation and the kinetic energy of raindrops, resulting in the destruction of structural aggregates.

When cultivating agricultural crops without tillage, the root layer does not experience the mechanical effect of soil-cultivating tools. Therefore, its structure remains intact, on which the volume of living space for soil microorganisms largely depends – capillary and non-capillary boreholes

The data on the volumetric mass of the soil in fallow showed the advantage of non-moldboard tillage in all layers from 0 to 30 cm – Table 1.

The highest density of the soil was in the variant with surface treatment when sowing safflower with the DON-114 seeder and amounted to 1.22-1.39 g/cm^3 depending on the layer. Optimal addition was provided by dump and non-dump processing of 1.14-1.25 g/cm^3 in the middle layer of 0-30 cm. When sowing spring crops without tillage, the working bodies of the seeder (turbo disc, coulter) loosen only the top layer of the soil to a depth of 6-8 cm. The underlying soil layers are not loosened. Therefore, and due to the physical properties of light chestnut soils predisposed to self-compaction, the density of all studied horizons before sowing was higher than according to traditional technologies and amounts to 1.26-1.27 g/cm^3 in the 0-10 cm layer, in the layer 10-20 cm - 1.33-1.39 g/cm^3 and in a layer 20-30 cm - 1.28-1.29 g/cm^3.

To analyze soil compaction, evaluation criteria are used when the density is 1.15 g/cm^3 or less, the soil is considered loose, 1.15-1.25 g/cm^3 compacted, 1.25-1.35 g/cm^3 - dense, and above 1.35 g/cm^3 - very dense. The main cultivation of the soil for grain crops should provide them with a compaction density of 1.05-1.30 g/cm^3, and when it increases, the productivity of crops decreases. With an increase in density by 0.01 g/cm^3, the yield of winter wheat decreases by 0.02 t/ha, spring crops by 0.03-0.04 t/ha, while the upper limit of the optimal density for light chestnut soils is 1.32 g/cm^3, which provides sufficient air regime for grain crops.

We observed the quality parameters of the main processing (depth, ridges, clumping), determined the preservation of stubble on the soil surface, as a means of protecting the soil from blowing small particles and allowing to retain the maximum amount of snow in the fields. In our experience, plant residues during harvesting were crushed and evenly distributed by the combine on the soil surface.

According to the technology without soil treatment all crop residues remain on the soil surface. On average, over the years of research, their number amounted to 3.58 t/ha, which is 2-6 times more than by traditional technologies, where it remained 0.6; 1.9; 1.6 t/ha, respectively - Table 2.

The conducted observations of the quality of the tested soil treatments (Table 3), showed that they make it possible to ensure the fulfillment of modern agro-technological requirements at the proper level, deviations from the given depth did not exceed 3 cm and corresponded to the optimal technological tolerance (10-15%). Surface treatments carried out to a minimum depth leave a more leveled surface, while

Table 1. Influence of main treatments on bulk density, g/cm^3, (average for 2016 - 2019)

Processing option, culture	Horizon, cm			
	0-10	10-20	20-30	0-30
Moldboard processing, PN-4-35	1,12	1,36	1,38	1,30
Moldless processing, OCHO-5-40	1,09	1,10	1,22	1,14
Surface treatment, BDM-4.2	1,14	1,38	1,30	1,27
Chemical steam	1,17	1,29	1,31	1,25
Safflower for dump processing	1,08	1,22	1,14	1,14
Safflower for non-dump processing	1,23	1,30	1,21	1,25
Safflower for surface processing	1,27	1,39	1,22	1,29
Safflower for winter wheat	1,26	1,33	1,27	1,28

Table 2. Influence of technology on the amount of plant residues on the soil after the main treatment and direct sowing, t/ha, (average for 2016 - 2019)

Technology	Processing	Year				Average value
		2016	2017	2018	2019	
Traditional	Moldboard PN-4-35	0,72	0,61	0,47	0,52	0,58
	Moldless OCHO-5-40, “Ranch”	1,91	2,07	1,73	1,93	1,91
	Surface BDM-4,2	1,47	1,66	1,36	1,85	1,58
Without treatment	Direct sowing	4,21	4,74	3,81	1,57	3,58

Table 3. Determination of the quality of basic tillage (average for 2016 - 2019)

Type of treatment	The planned depth, cm	Actual depth, cm	Alignment coefficient, %	Lumpiness of the surface, %	Ridge of the surface, %
Moldboard	25-27	23,5	68,33	44,07	30,33
Moldless	25-27	25,7	79,73	24,52	26,33
Surface	8-10	8,9	70,11	12,44	16,66

deep treatments leave a more ridged surface. The highest ridges corresponded to the option with a dump treatment to a depth of 25-27 cm and amounted to 30.3%. Mold less tillage to the same depth had a ridging of 26.3%. Surface treatment to a depth of 8-10 cm forms a ridge 1.5-2.0 times less, compared to deep treatments. Lumpiness of the surface soil layer did not exceed 12-24% on stubble variants, and it was 44% on moldboard cultivation.

Processing itself does not bring anything to the soil, but it depends on the agrophysical characteristics of the soil, which determine the water-air and thermal conditions of the soil climate, the degree and depth of embedding of plant residues. Depending on the methods of basic processing, one or another structure of the soil profile is formed according to the distribution of particles of the solid phase, reserves of nutrients, the movement of carbon dioxide and moisture. All this can affect the dynamics and ratio of humus synthesis and mineralization, the formation of mobile forms of nutrients and their development by plants. Currently, the question of methods and depth of tillage as methods of regulating the physical state of the upper soil layer is discussed from the perspective of transition to conservation agriculture and is associated with its structuring and the formation of a mulching layer from plant residues of varying degrees of decomposition.

According to the criteria of the aggregate composition of the soil, the following structural units are distinguished: large (10 mm), lumpy-granular (10 - 0.25 mm) and microaggregates (0.25 mm), where aggregates of 10-0.25 mm are agronomically valuable.

The general dynamics of aggregates can be traced through the coefficient of soil structure - Table 4.

Chemical steam is subjected to the least mechanical impact, so the SC (structural coefficient) is the highest and is 7.73The balance of the aggregate composition of the soil in the chemical steam shows minor changes in both macro and micro aggregates, which indicates that the NO-TILL technology prevents the destruction of the upper soil layer, preserves the structure and prevents soil degradation. The number of agronomically useful aggregates (10.0-0.25 mm) on average during the fallowing period is 88% - this is an indicator of a well-structured soil.

In spring crops and winter wheat, the transition from a large fraction to a dust-like one is much more intense. The destruction of the lumpy fraction in winter wheat crops is 90% stronger than in the

Table 4. Dynamics of the structural and aggregate state of the soil, dry seeding, % (average for 2016 - 2019)

Indicator	May	August	Balance+/-
Moldboard processing, PN-4-35			
Blocks, >10 mm	6,31	5,96	-0,35
Macrostructure, 0.25-10 mm	70,7	72,2	-4,1
Microstructure, < 0.25 mm	17,39	21,84	+4,45
Structural coefficient	3,2	2,6	-0,6
Moldless processing, OCHO-5-40, «Ranch»			
Blocks, >10 mm	4,7	1,69	-3,01
Macrostructure, 0.25-10 mm	80,4	84,18	+3,78
Microstructure, < 0.25 mm	14,9	14,13	-0,77
Structural coefficient	4,1	5,3	+1,2
Surface treatment, BDM-4.2			
Blocks, >10 mm	3,88	1,93	-1,95
Macrostructure, 0.25-10 mm	79,2	81,67	+2,47
Microstructure, < 0.25 mm	16,92	16,4	-0,52
Structural coefficient	3,8	4,4	+0,6
Chemical steam			
Blocks, >10 mm	4,67	4,22	-0,45
Macrostructure, 0.25-10 mm	88,54	87,9	-0,64
Microstructure, < 0.25 mm	6,79	7,88	+1,09
Structural coefficient	7,73	7,26	-0,47
Spring crops (direct seeding)			
Blocks, >10 mm	5,7	4,88	-0,82
Macrostructure, 0.25-10 mm	87,92	82,79	-5,13
Microstructure, < 0.25 mm	6,38	12,33	+5,95
Structural coefficient	7,23	4,8	-2,43
Winter wheat (direct seeding)			
Blocks, >10 mm	9,94	1,14	-8,8
Macrostructure, 0.25-10 mm	87,42	85,49	-1,93
Microstructure, < 0.25 mm	2,64	13,37	+10,73
Structural coefficient	6,95	5,89	-1,06

soil under spring crops, but macrostructures (0.25-10 mm) are more prone to disintegration and transition to a fine fraction in barley crops than in winter wheat. However, these indicators are low and indicate that the preservation of stubble when grown using NO-TILL technology prevents soil degradation.

Positive indicators in the microstructure increase (<0.25) are the highest in the soil under winter wheat and amount to + 10.73%. On chemical steam and barley, this indicator is +1.09% and +5.95%, respectively. The overall structural coefficient for the study period was 7.5 for chemical steam, 6.0 for barley, and 6.4 for winter wheat.

The total content of macroaggregates in the soil layer 0-0.3 m under the influence of its treatment fluctuated in the range with treatment of 76.3-80.4%. Most of the macro-aggregates were destroyed during the care of the steam on the moldboard tillage by 4.1%, which is associated with the intense impact of mechanical treatments on the soil, while subsurface and surface treatments was on the contrary an increase in macroaggregates of 2-4 % where due to the influence of aerobic bacteria occurs mineralization of organic matter, thus cementing the structural basis.

The structural coefficient for the main tillage by the end of fallow was 2.6 for dump, 5.3-4.4 for non-dump and surface, respectively.

Analysis of elements of mineral nutrition in the spring and summer period shows that nitrates in the soil accumulate more intensively on dump and non-dump treatments, and mobile phosphorus and exchange potassium have a negative balance on the chemical level - Table 5.

During the dump treatment, the nitrate nitrogen reserves were 1.07 mg/100 g of soil on the non-dump 1.14 mg/100 g and surface 1.24 mg/100 g of soil at the beginning of the fallow period, at the end of the fallow period, this indicator increased to 9.1; 6.0, and 2.8 mg/100 g in the 0-30 cm soil layer, respectively. The main tillage on the accumulation of phosphorus had an impact only on the dump and non-dump background balance +1.1, +2.6 mg/100 g, on the surface and chemical steam accumulation did not occur. The availability of exchange potassium in the soil was high in all tillage options and the negative balance was on chemical steam.

CONCLUSIONS

The highest density of the soil was in the variant with surface treatment when sowing safflower with the DON-114 seeder and amounted to 1.22-1.39 g/cm3 depending on the layer. Optimal addition was provided by dump and non-dump processing of 1.14-1.25 g/cm3 in the middle layer of 0-30 cm. When sowing spring crops without tillage, the density of all the studied horizons was higher than in traditional technologies and is 1.26-1.27 g/cm3 in the 0-10 cm layer, 1.33 - 1.39 g/cm^3 in the 10-20 cm layer, and 1.28-1.29 g/cm^3 in the 20-30 cm layer. On average for the crop rotation during moldboard cultivation, the soil layer 0-30 cm in spring contained macroaggregates (particles from 0.25 to 10 mm) - 70.7%, with non-moldboard tillage 80.4%, and with surface tillage 79.2%, to at the end of the growing season, the average value for the content of macroaggregates for treatments was 72.2%, 84.18%, 81.67%, respectively. In the crop rotation without treatments, these values by the end of the growing season were higher and amounted to 87.9%, 82.8% and 85.5%, respectively. The content of water-resistant aggregates ranged from 2.6 to 17.4% depending on the variant of the main tillage, the smallest was on the surface in black fallow, the highest against the background of moldboard-free for spring crops. The highest ridging corresponded to the option with moldboard processing to a depth of 25-27 cm and amounted to 44.1%. Moldless tillage to the same depth had a ridge of 24.5. Surface treatment to a depth of 8-10 cm forms a ridging 1.5-2.0 times less than deep treatments.

Table 5. Food regime in the soil under main treatment and chemical steam (average for 2016 - 2019), mg/100 g of soil

Variant	Horizon, cm	Elements of mineral nutrition, mg/100 g of soil								
		NO_3			P_2O_5			K_2O		
		April	August	+/-	April	August	+/-	April	August	+/-
Steam Moldboard processing, PN-4-35	0-10	1,15	12,81	+11,6	5,08	7,25	+2,17	30,00	33,6	+3,6
	10-20	0,86	10,29	+9,43	5,02	6,83	+1,27	26,67	36,75	+10,1
	20-30	1,2	7,39	+6,19	4,82	7,20	+2,57	26,04	37,28	+11,2
steam Moldless processing, OCHO-5-40	0-10	1,31	9,45	+8,14	6,59	7,67	+1,08	39,53	43,16	+3,63
	10-20	0,80	6,97	+6,17	6,3	7,25	+0,95	27,45	28,85	+11,4
	20-30	1,30	5,08	+3,78	5,06	7,46	+0,02	21,42	33,08	+11,6
Steam Surface treatment, BDM-4.2	0-10	1,17	4,05	+2,88	8,5	7,56	-0,94	29,00	36,75	+7,7
	10-20	1,15	5,25	+4,10	8,63	7,67	-0,96	26,14	31,29	+5,1
	20-30	1,4	2,79	+1,39	8,24	6,72	-1,52	22,42	26,88	+4,4
Chemical steam	0-10	0,34	1,53	+1,19	6,51	5,1	-1,41	44,52	31,50	-13,0
	10-20	0,59	1,78	+1,19	6,09	4,35	-1,74	36,43	22,05	-14,4
	20-30	0,48	1,41	+0,93	5,65	4,58	-1,07	35,49	26,04	-9,4

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