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Research paper

The Effect of the Methods of Basic Soil Treatment on its Agrophysical Parameters

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Abstract

The article presents the results of years of research conducted in order to establish the optimal parameters of agrophysical soil properties with different ways of its treatment in the agrotechnologies of row crop production. The studies were conducted on the following soil treatment systems: plowing the soil to a depth of 25-27 cm (at a stretch (control); chisel soil treatment to a depth of 38-40 cm (at a stretch); surface treatment of the soil to a depth of 10-12 cm (at a stretch); and combined soil treatment system. The study demonstrated the typical relationship between the structure and density of the compact chernozem, different for the seed and the underlying layers. The parameters of the agrophysical indices of the compact chernozem, which are actually attainable over the arable layer and favorable for tilled field crops, have been theoretically justified and experimentally confirmed.
It has been found that for compact chernozem with high and persistent water stability (more than 68%) of the soil structure, unfavorable agrophysical indices are characteristic, sharply differentiated according to its layers: 1) the amount of blocky soil suite (structural aggregates of more than 10.0 mm) can reach 55% in the upper and 90% in the underlying layers of the arable layer; 2) the density of the arable layer of the soil is reduced to 0.94 g/cm3, while in the 15-25 cm and 30-40 cm layers it increases to 1.34 g/cm3.
A correlation has been found between the density and share of the blocky fraction, negative in the 0-10 cm soil layer, and positive in the deeper layers. With an increase in the share of the blocky fraction, the upper layer of the soil acquires a loose structure (total porosity of above 60%), and the lower layers are compacted with a decrease in porosity to 50%.

Keywords: *soil, compact leached chernozem, soil structure, soil density, granulometric composition, porosity, row crops, corn, sunflower, soil treatment, yield.*

1. Introduction

Soil resources of the plain part of the Republic of Adygeya are represented by various soil types, but the compact and leached chernozems are the main agronomically relevant ones. These subtypes of chernozems are formed on a loesslike parent rock. Over the past few years, there has been an intensive process of compaction, which affects agrophysical properties of chernozems and the crops grown on these soils subtypes [6, 9, 21, 22, 23].
Improvement of agrophysical parameters of soils provides a favorable condition of water-air, salt and heat regimes, and promotes the activation of the microbiological processes in order to improve nutritional status. Ultimately, the importance of the agrophysical indicators significantly affects the yield. Well-structured soils are more resistant to erosion and deflation [1, 4, 5, 18].
Water stability of chernozems (leached and compact), prevailing in the soil cover of the Republic of Adygeya is high [2, 3, 7, 10]. The water stability values are significantly more persistent by years compared with the structural-aggregate composition [16, 17]. The structural state is a descriptive character of soils, depending on the granulometric composition and humus content [17]. The vegetation cover has a decisive impact on the structural state [12, 15].
The degree of the root system development in many respects determines the degree of influence of vegetation on the formation of soil structure. The powerful root system of perennial grasses causes their greater influence on the process of structure formation than that of annual crops. The structure formation process takes place under the action of plants: Stage 1 - the division of the soil mass by the root system into aggregates and the aggregation of these aggregates by the plant residues decomposition products; Stage 2 - the formation of a waterproof structure – the process that takes place with the direct participation of herbaceous plants growing in a given territory. It is more intensive under meadow plants. They permeate the soil with a dense network of roots, dividing it into small parts. With the decay of the accumulating mass of dead roots, fresh (active) humus is formed, which gradually permeates the soil lumps. In the soil, it is coagulated by calcium and magnesium compounds and rendered insoluble. In the case of soil drying or freezing, freshly deposited humus rather severely cements the separate mechanical elements and aggregates, providing them with high water stability. Thus, herbaceous plants play a special role in the increase in the water stability of the soil structure being created. Chernozem soils have the highest water stability, and herbaceous plants play an important role in their formation.

The main purpose of this work is to synthesize the results of years of research to establish the optimal parameters of agrophysical soil properties with different ways of its treatment in the agrotechnologies of row crop production.

2. Objects and Methods

To achieve this goal, field experiments were carried out for three years (2015-2017) to compare the agrophysical properties of soils with different methods and systems of basic soil treatment on compact chernozem in the territory of Raduga Agricultural Academy in the Gyaginsky District of the Republic of Adygea, in sunflower and corn fields. The most agronomically valuable upper root zone of the soil was studied in the experiment, thus, the soil samples for analysis were taken at 10 cm to a depth of 40 cm.
The experiment has been carried out in order to eliminate the "gaps" found in the analysis of the previous experiments results. According to the working assumptions, it was expected that the selection of treatment method taking into account the state of soil humidity would improve the agrophysical soil properties of compact chernozem with a relevant increase in yield.
The total (sowing) area of the experimental plots was in the range of 2,250 m2 (15 x 150) – 2,500 m2 (10 x 250). The accounting area - no less than half of the sowing one, proving to be unequal in some cases (spacings for various objective reasons).
The scheme of this experiment includes the following treatment system options: 1) plowing the soil to a depth of 25-27 cm at a stretch (control); 2) chisel soil treatment to a depth of 38-40 cm; 3) surface treatment of the soil to a depth of 10-12 cm (at a stretch); and 4) combined soil treatment system. The latter was not correlated with the order of crops alternation but was based only on the choice of the method of basic soil treatment by the time of its implementation, taking into account the amount and distribution of moisture in the forty-centimeter soil layer.

3. Results and Discussion

On average, over the years of research, much prominence in structural-aggregate condition and remoteness from the optimal parameters with a small share of separates of less than 0.25 mm was observed in the experiments. Taking into account the unhandiness of the tables in the detailed presentation of the experimental data, Tables 1 and 2 contain information summarized in the pedality indexes.
The soil pedality index under corn (Table 1) significantly changed during the research and the lowest one was observed in 2015, since in September (in the preceding autumn) 1.5 precipitation rates had fallen on the background of 155 mm in August (more than a third in the last decade), and in October - three rates. Due to the treatment of the waterlogged soil for the harvest of the year, the content of the blocky fraction exceeded the quantitative limit of the strong excess of the optimum in the 0-10 cm layer by almost half (52-55%), and in the lower layers - three times (86-92%). For the 2015 yield, in the combined treatment system, according to the general plant, the surface treatment should have been conducted. However, given the large spread of perennial weeds, the wrong decision was made - plowing.

Table 1: Soil pedality index under corn, depending on the methods and systems of soil treatment, %

Option basic soil treatment	Soil layer, cm	Year			Average
		2015	2016	2017	
Plowing to a depth of 25-27 cm (at a stretch)	0-10	1.0	3.2	1.8	2.0
	15-25	0.1	0.3	0.2	0.2
	30-40	0.2	0.4	0.3	0.3
Chisel to a depth of 38-40 cm (at a stretch)	0-10	0.8	3.2	3.9	2.6
	15-25	0.1	0.3	0.3	0.2
	30-40	0.2	0.2	0.3	0.3
Surface to a depth of 10-12 cm (at a stretch)	0-10	0.9	3.0	3.8	2.5
	15-25	0.3	0.3	0.2	0.3
	30-40	0.2	0.3	0.3	0.3
Combined treatment system	0-10	1.0	3.2	3.9	2.7
	15-25	0.1	0.3	0.3	0.2
	30-40	0.2	0.4	0.3	0.3

Note: in the version of the combined soil treatment system the following activities were carried out: 2015 – plowing; 2016 – plowing; 2017 – chisel treatment.

For the yield of 2016 and 2017 plowing and chisel treatment, respectively, were chosen correctly. Over the years of the conducted studies, on average, the option with an adjustable combination of soil treatments provided a better structural state.
The optimum value of the pedality index for chernozems with heavy granulometric composition is at the level of 3.3 units (the dimensionless value). On average over the years of research, it was closest to this value under corn in the 0-10 cm layer of the combined treatment system option, and in 2016 it practically corresponded to the optimal value.
Data on the structure of the soil under sunflower are shown in Table 2.

Table 2: Soil pedality index under corn, depending on the methods and systems of soil treatment, %

Option basic soil treatment	Soil layer, cm	Year			Average
		2015	2016	2017	
Plowing to a depth of 25-27 cm (at a stretch)	0-10	3.6	4.2	4.4	4.1
	15-25	0.2	0.3	0.2	0.2
	30-40	0.3	0.3	0.3	0.3
Chisel to a depth of 38-40 cm (at a stretch)	0-10	3.8	4.6	4.4	4.3
	15-25	0.3	0.4	0.2	0.3
	30-40	0.3	0.4	0.2	0.3
Surface to a depth of 10-12 cm (at a stretch)	0-10	3.0	4.3	3.7	3.7
	15-25	0.3	0.3	0.4	0.3
	30-40	0.3	0.5	0.4	0.4
Combined treatment system	0-10	3.7	4.8	3.7	4.1
	15-25	0.2	0.3	0.4	0.3
	30-40	0.4	0.4	0.5	0.4

Note: in the version of the combined soil treatment system the following activities were carried out: 2015 – plowing; 2016 – chisel treatment; and 2017 – surface treatment.

In case of the combined treatment system, all methods of basic treatment studied in the experiment were used: for the 2015 crop, plowing to a depth of 25-27 cm (out of 121 mm of precipitation in October of the previous year 28 mm fell out in the first half of the month, i.e. by the end of the experiment); for the 2016 crop - chisel soil treatment (dry preceding autumn); for the 2017 crop - surface treatment of the soil to a depth of 10-12 cm (approximately three standards of the atmospheric precipitation in September against the background of four August standards).
In all cases, the combined sunflower treatment systems had been selected correctly. As can be seen from Table 2, the values obtained with the combined treatment system and using the same regular treatments, were the best for all years of the study. On average for three years, respectively, the best indicators were achieved in the option of the combined system of basic treatment of compact chernozem.
It should be noted that, on average and in the context of individual years, the differences in the options were insignificant in the 0-10 cm layer (where the pedality index on the average for the years of research was the most approximate to the optimal value), and in deeper layers they were 1.5-2.0 times smaller. In the case of soil treatment with moisture exceeding its value in physical ripeness, the best structure in the deep layers was found by surface treatment. The negative effect in the options of plowing and chisel

treatment of moist soil was manifested in the 15-25 cm and 30-40 cm layers, respectively.

Bulk density is another equally important physical property of soils. Knowledge of soil density allows determining the porosity, moisture reserves, and nutrients in the soil necessary for calculating irrigation rates and the number of fertilizers applied. The structural soil has the smallest value interval between the optimum and equilibrium density, and in well-cultivated soils, their values may coincide like, for example, in chernozems.

Due to extensive research, the issue of the unequal reaction of field crop plants to density became a well-known fact. The density of the soil in question should be assessed in conjunction with other agromechanical and agrophysical indicators. The optimum values of the density of chernozem soils in the central part of the Krasnodar Territory for a number of field crops are provided in Table 3.

Table 3: Optimal soil density (g/cm3) for growing crops on the chernozems of Kuban (generalized material) [8]

Soil type	Crop				
	Winter wheat	Sugar beet	Corn	Sunflower	Alfalfa
Leached chernozem	1.22-1.30	1.10-1.20	1.16-1.23	1.20-1.30	1.10-1.38
Common chernozem	1.15-1.27	1.10-1.20	1.25-1.32	1.15-1.27	1.27-1.35
Compact chernozem	1.24-1.27	1.23-1.29	1.22-1.29	1.21-1.33	-

It can be seen from the above material that for compact chernozem the range of density values achievable to establish better conditions for sugar beet, corn and sunflower is shifted by 0.13-0.06 g/cm3 compared to leached chernozem.

The data on the density of compact chernozem under corn and under sunflower are shown in Tables 4 and 5, respectively.

Table 4: Soil density under corn, depending on the methods and systems of basic soil treatment, g/cm3

Option of the basic soil treatment	Soil layer, cm	Year			Average
		2015	2016	2017	
Plowing to a depth of	0-10	0.99	1.05	1.01	1.02
25-27 cm (at a stretch)	15-25	1.33	1.19	1.24	1.25
	30-40	1.31	1.22	1.29	1.27
Chisel to a depth of	0-10	0.96	1.06	1.00	1.01
38-40 cm (at a stretch)	15-25	1.26	1.22	1.19	1.22
	30-40	1.30	1.24	1.23	1.26
Surface to a depth of	0-10	0.95	1.07	1.02	1.01
10-12 cm (at a stretch)	15-25	1.22	1.17	1.19	1.19
	30-40	1.28	1.23	1.29	1.27
Combined treatment system	0-10	0.99	1.05	1.00	1.01
	15-25	1.29	1.19	1.18	1.22
	30-40	1.29	1.20	1.22	1.24

Table 5: Soil density under sunflower, depending on the methods and systems of basic soil treatment, g/cm3

Option of the basic soil treatment	Soil layer, cm	Year			Average
		2015	2016	2017	
Plowing to a depth of 25-27 cm (at a stretch)	0-10	0.99	1.00	1.10	1.03
	15-25	1.18	1.23	1.25	1.22
	30-40	1.26	1.29	1.26	1.27
Chisel to a depth of 38-40 cm (at a stretch)	0-10	0.97	1.08	1.09	1.05
	15-25	1.19	1.18	1.22	1.20
	30-40	1.27	1.24	1.30	1.27
Surface to a depth of 10-12 cm (at a stretch)	0-10	0.96	1.05	1.11	1.04
	15-25	1.20	1.21	1.17	1.19
	30-40	1.28	1.25	1.25	1.26
Combined treatment system	0-10	0.99	1.08	1.11	1.06
	15-25	1.17	1.18	1.18	1.18
	30-40	1.25	1.25	1.24	1.25

The data of the table reflected a difference in the density of the seed layer under corn, and in the context of individual years it was: 0.95-0.99 g/cm3 in 2015 (humid preceding autumn); 1.05-1.07 g/cm3 and 1.00-1.02 g/cm3 in 2016 and 2017, respectively, i.e. in terms of this experiment options, the differences were insignificant.

In 2015, in the plowing option, soil compaction was noted in a 15-25 cm layer, and maximum density - in a 30-40 cm layer.

The soil density was found to be the most optimal and smallest in all the years of research in the 15-25 cm layer in the surface treatment option, where it was practically not affected by tillage tools. At the same time, the soil density in the 30-40 cm layer was set at the level of plowing to a depth of 25-27 cm.

This trend continued also under sunflower when studying systems of basic compact chernozem processing: low density of the topsoil with minor differences between options; compaction of the middle and lower parts of the treated soil strata when ploughing and chisel treatment, respectively; less intensive compaction of the 15-25 cm soil layer in the option with the surface treatment of the soil.

In case of the combined soil treatment system, the density values in terms of the selected primary processing methods are generally identical to the values of application of the individual methods at the stretch.

The researched allowed discovering certain regularities: 1) the differentiation of the layer under investigation increases with depth by the density of the soil; 2) in the middle and lower parts of the 0-40 cm layer, the soil density does not exceed the critical values; 3) in the sowing layer of soil, the density is usually lower than the optimal one; 4) the value of soil density is largely determined by the moisture content of the soil during its treatment (as well as its structure) rather than directly by the methods of treatment thereof; and 5) in the context of the experiment options studied, differences in the soil density in the 15-25 cm layer are found mainly in the treatment of physically unripe soil.

When analyzing the porosity of the compact chernozem, it can be noted that by its natural properties it’s characterized by an unfavorable close ratio of capillary and non-capillary porosity [19, 20], i.e. an increase in the total porosity leads simultaneously to an increase in its non-capillary share. Even at a total porosity of 55%, the non-capillary one exceeds the optimum value.

In view of the foregoing and in the absence of an evaluation scale, as an acceptable interval, the total porosity in the range of 58-52% was used, which does not contradict the existing (unequal) estimates for chernozem soils (Table 6).

Table 6: The total porosity of the compact chernozem under corn, depending on basic soil treatment, %

Option of the basic soil treatment	Year	Soil layer, cm		
		0-10	15-25	30-40
Plowing to a depth of	2015	64.9	48.7	52.6
25-27 cm (at a stretch)	2016	63.7	55.0	57.3
	2017	59.6	49.9	55.1
	average	62.7	51.2	55.0
Chisel to a depth of	2015	66.6	52.0	48.4
38-40 cm (at a stretch)	2016	59.9	57.3	55.2
	2017	57.7	52.4	57.6
	average	61.4	53.9	53.7
Surface to a depth of	2015	66.8	53.1	49.3
10-12 cm (at a stretch)	2016	54.2	52.8	52.5
	2017	62.0	54.6	56.6
	average	61.0	53.5	52.8
Combined treatment system	2015	63.2	50.0	52.7
	2016	57.0	56.1	55.9
	2017	57.5	53.7	56.7
	average	59.2	53.3	55.1

content From the data in Table 6 (the results of the studies under corn), a significant differentiation in porosity between the upper and lower layers was seen downwards from the first one (in most cases, the porosity values exceeded 60%) to 57.3-48.7% in the 15-25 cm layer, and 57.3-48.4% in the 30-40 cm layer.

While in the 0-10 cm layer the differences in terms of the experiment options were insignificant, in the deeper ones they were very noticeable, where they depended on the state of ripeness of the soil during the treatment period.

Thus, in 2015, in 15-25 cm layer, the plowing effect was negative with a porosity of 48.7% (also 50.0% in the combined system option, with the use of the incorrect treatment method in that year). In 2015, the porosity value was low in case of chisel treatment in a layer of 30-40 cm, which is also explained by the depth of treatment with abundant precipitation in the preceding autumn.

In all years porosity in the surface treatment option was quite acceptable and close in its magnitude in the layer of 15-25 cm. This cannot be said concerning the lower third of the investigated soil thickness, where in 2015 porosity proved to be inexplicably low. On average over the study period, somewhat better values have been obtained with the combined treatment system.

The results of porosity determination under sunflower do not contradict the ones observed under corn: the contrast in the investigated layers is similar; there is no difference in terms of the experimental options in the 0-10 cm layer (Table 7).

Table 7: The total porosity of the compact chernozem under sunflower, depending on basic soil treatment, %

Option of the basic soil treatment	Year	Soil layer, cm		
		0-10	15-25	30-40
Plowing to a depth	2015	62.1	57.4	56.0
	2016	64.1	54.5	55.8
25-27 cm (at a	2017	64.6	49.2	53.5
	average	63.6	53.7	55.1
Chisel to a depth	2015	64.0	52.6	53.0
	2016	60.7	56.9	58.5
38-40 cm (at a	2017	61.3	50.7	48.4
	average	62.0	53.4	53.3
Surface to a depth	2015	65.6	52.8	53.0
	2016	65.0	55.5	54.2
10-12 cm (at a	2017	60.5	54.0	50.3
	average	64.5	54.1	52.5
	2015	62.9	53.7	54.0
Combined	2016	60.8	56.5	56.2
ystem*	2017	59.9	54.8	52.7
	average	61.8	55.0	54.3

**In the combined treatment system, in the preceding years, the following actions had been performed: 2015 – plowing, 2016 and 2017 - chisel and surface treatments.*

The best porosity values were obtained in 2015, for plowing; in 2016 for chisel treatment, and in 2017 for surface treatment. As a result, on average over the years of research, the best results have been achieved in the combined treatment system option.

In the treatment of compact chernozem for the 2017 crop, the preceding autumn had turned out to be humid. This resulted in the deterioration in porosity in the 15-25 cm layer (49.2%) after plowing, and in the 30-40 cm layer (48.4%) - after chisel treatment.

After the surface treatment, it was close to the optimal value in the middle part, but at the lower limit of an acceptable interval in the 30-40 cm layer, which is inexplicable from the position of the influence of the working organs of the tillage tools.

It must be highlighted that in both cultures the porosity values in the combined system option virtually coincided with the values in those processing options, which were performed in the combined system.

Information on the ratio of intra-aggregate and inter-aggregate pores is not provided since the fraction of non-capillary pores turned out to be much larger than necessary for normal gas exchange and amounted to almost half of the total porosity. The ratio of non-capillary and capillary intervals, resulting from the main processing methods, was not always unfavorable. In the studies of N.I. Mamsirov [11, 13, 14, 24] there were 7-14% more capillary pores under chisel soil treatment compared to plowing (in the 15-25 cm layer).

The very fact of the existence of interrelations between the parameters of the agrophysical state is quite probable. In the aggregate of arguments proving this assertion, the correlation between them (positive or negative) can be the most significant one.

From the materials given in the previous sections of this chapter, it is evident that the water stability of the structure is greater than that of significant structural-aggregate composition fluctuations, which is consistent with the results of other studies.

The density of the compact chernozem in the experiments was relatively stable due to the dynamics toward the equilibrium state, and the fluctuations in the total porosity were at an intermediate position.

The stability of the structural-aggregate composition of compact chernozem by years is shown in Figure 1. Calculation of the variation and leveling index is based on the magnitude of the pedality indexes, the values of which were provided earlier in Tables 1 and 2.

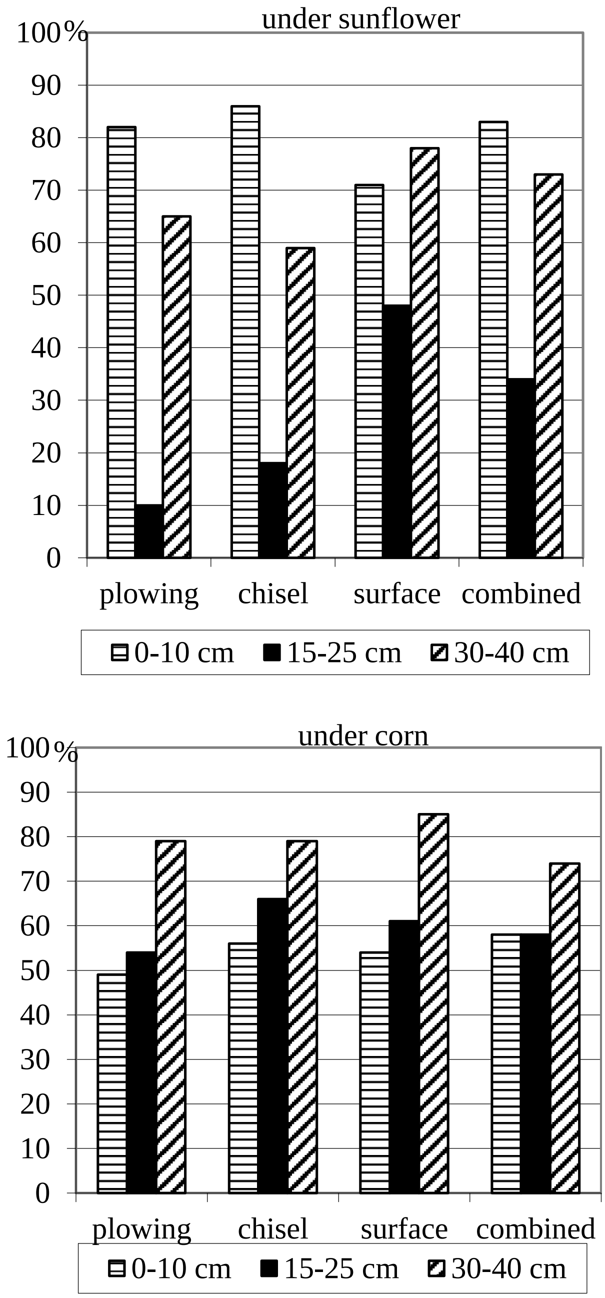


Figure 1: Leveling factor (%) (stability by years) of soil structure depending on soil treatment in layers

The magnitude of the resistance (the opposite to variation) is not the basis for approval - this technique or factor is better, and the other - worse. The explanation for this is simple: both good and bad properties are stable. This is confirmed by a higher stability in the worst structure under corn than under sunflower (for the 15-25 cm layer).

Practically in all cases of soil treatment (in the 0-10 cm layer), a high stability of the structural aggregate composition (under the influence of soil-cultivating tools) was observed also in the 30-40 cm layer, which was affected only by deep subsurface loosening.

In the 15-25 cm layer under both cultures, the resistance increased in a row: plowing, deep subsurface and surface treatment.

Stability in this layer with a combined soil treatment system was lower compared to surface treatment at a stretch, which should be regarded as a positive fact explained by the relatively better structural and aggregate state.

The contents of Figure 1 do not help clarify the issue of the relationship, since the structure is expressed quantitatively, and the correct evaluation methodology has not been found for this case. At the same time, the necessity (taking into account also the density and porosity data) of the choice of processing methods is clearly illustrated.

The assessment of correlation between the density of the fully compact chernozem and the fraction of the blocky (>10.0 mm) fraction was estimated. The most common result both for sunflower and corn (Table 8) is that for the 0-10 cm layer the sign of the correlation index is negative, and for the underlying one, it is positive.

Table 8: Correlation relationship between soil density and share of blocky fraction (>10.0 mm) (2015-2017)

Option of soil treatment	Soil layer, cm	r	d_{yx}	s_r	t_r
under sunflower					
Plowing to a depth of 25-27 cm (at a stretch)	0-10	-0.49	0.24	0.44	1.11
	15-25	0.41	0.17	0.46	0.89
	30-40	0.66	0.43	0.38	1.74
Chisel to a depth of 38-40 cm (at a stretch)	0-10	-0.77	0.59	0.32	2.41
	15-25	0.55	0.30	0.42	1.31
	30-40	0.13	0.02	0.49	0.27
Surface to a depth of 10-12 cm (at a stretch)	0-10	-0.57	0.32	0.41	1.39
	15-25	0.12	0.01	0.50	0.24
	30-40	0.09	0.01	0.50	0.18
Combined treatment system	0-10	-0.07	0.005	0.487	0.14
	15-25	0.51	0.26	0.35	1.46
	30-40	0.14	0.02	0.49	0.29
				$t_r$theor	2.78
under corn					
Plowing to a depth of 25-27 cm (at a stretch)	0-10	-0.29	0.08	0.48	0.60
	15-25	0.89	0.79	0.23	3.87
	30-40	0.73	0.52	0.35	2.09
Chisel to a depth of 38-40 cm (at a stretch)	0-10	-0.71	0.50	0.13	5.68
	15-25	0.95	0.89	0.17	5.59
	30-40	0.96	0.92	0.14	7.14
Surface to a depth of 10-12 cm (at a stretch)	0-10	-0.68	0.46	0.73	0.93
	15-25	0.36	0.13	0.22	1.64
	30-40	0.30	0.09	0.48	0.63
Combined treatment system	0-10	-0.47	0.22	0.88	0.53
	15-25	0.81	0.66	0.29	2.79
	30-40	0.87	0.75	0.25	0.35
				$t_r$theor	2.78

Designations: r – correlation index; dyx – determination index; sr correlation index error; tr – the criterion of the significance of the correlation index

The tightness of the correlation ratio was not high. In all cases, the criterion of the essentiality of the correlation did not exceed the $t_t$theor value.

Under corn, the coincidence of high correlation ratio and the importance of the correlation index were noted when plowing in the 15-25 cm layer, in all layers - with constant chisel treatment.

The most significant result of this study is reflected in Figure 2.

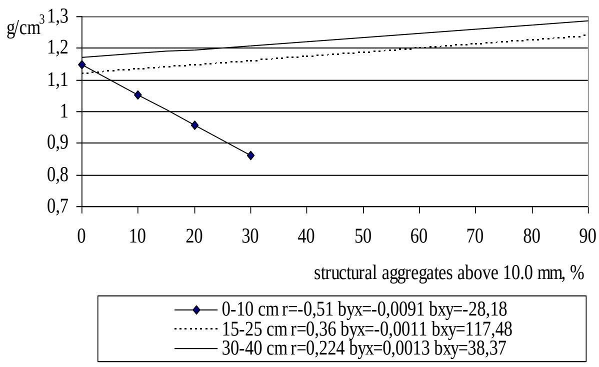
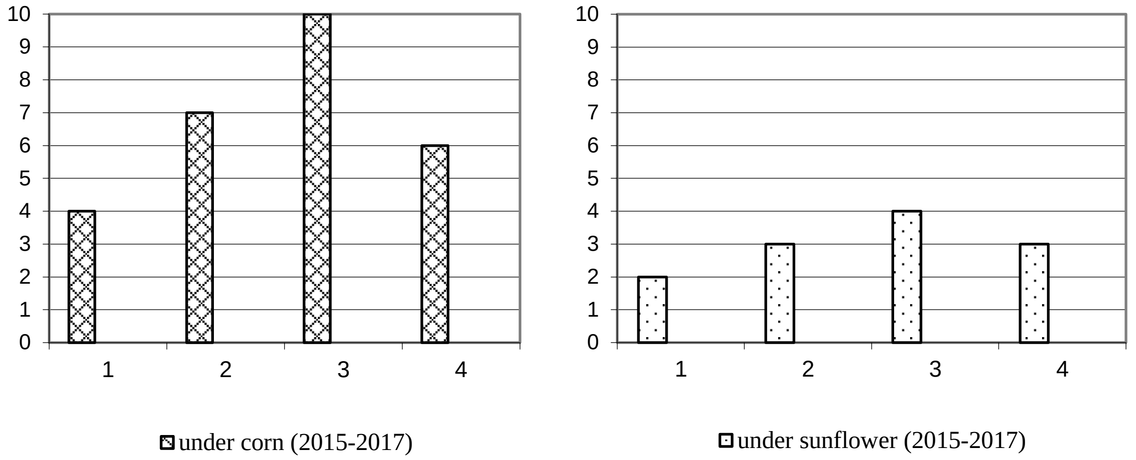


Figure 2: The lines of regression of soil density by the blocky fraction in the structure along the layers

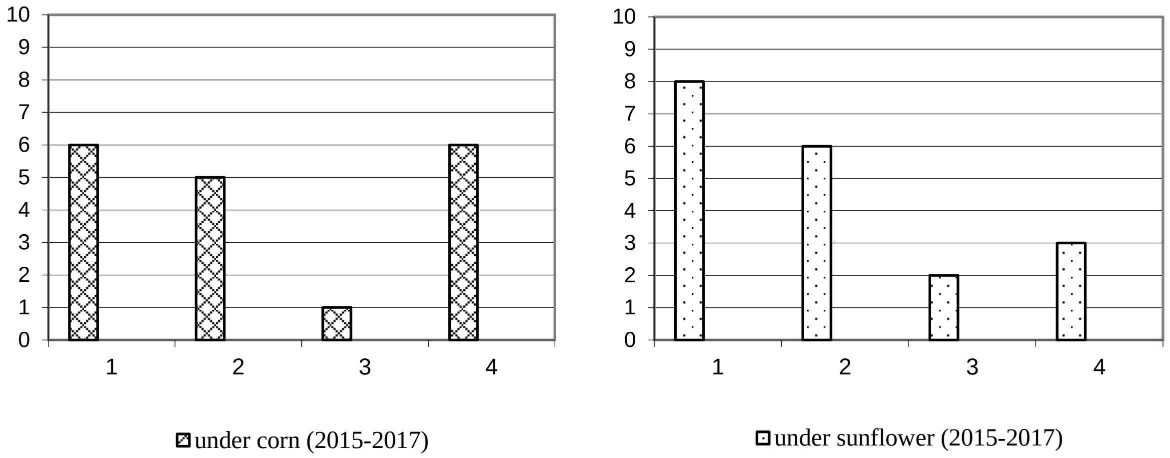
The regression equations have not been compiled for the following reasons: 1) the tightness of the correlation dependence is low; 2) linear nature is valid in the range of certain values; and 3) there is no practical need. The main purpose of the figure is to illustrate the different orientation of the correlation in the sowing and underlying layers of the soil.

as This is due to the objective possibility of a double arrangement of soil aggregates-cubic and hexagonal ones. In the first case, when the centers of the particles of the upper and lower rows are located on a vertical line, and the centers of all adjacent aggregates are in the corners of the cubic lattice, the loosest structure is ensured (the density is low, the pore volume considerably exceeds the volume of the solid phase of the soil). In the second case, when each particle of the overlying row is between the particles of the lower row, and the centers of the particles are the angles of an equilateral tetrahedron, the arrangement of the particles is the densest one (the volume of the solid phase of the soil considerably exceeds the pore volume, because of which the volume (density of structure) and specific gravity of the soil reach their maximum values [17].

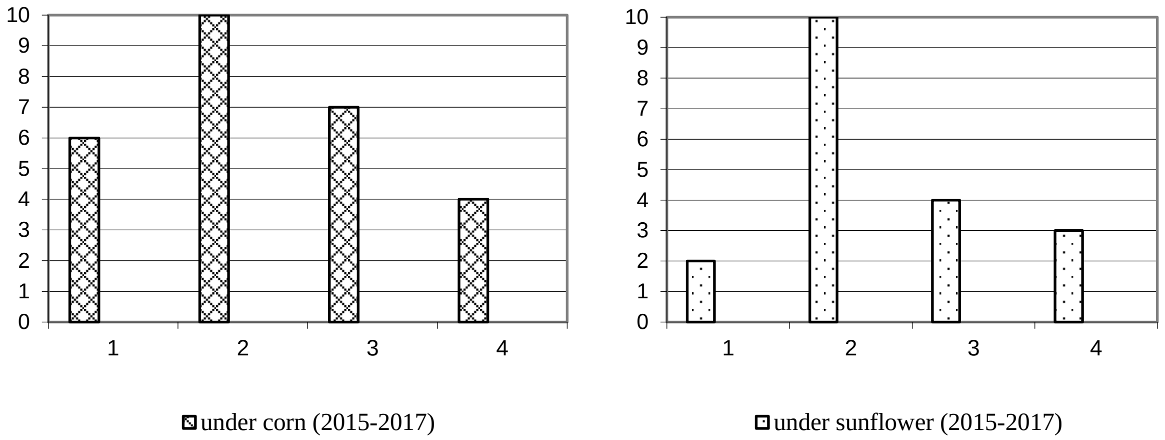
The above quotation explains the weakness of the correlation between the size of structural aggregates and the density of soil but does not deny the existence of a more complex relationship. Before considering the porosity as a function of structure and density, let us refer to Figure 3, which shows the variation in porosity due to the basic soil treatment.



0-10 cm layer



15-25 cm layer



30-40 cm layer

Figure 3: Coefficients of variation (column) and leveling* (numbers in columns) of soil porosity under corn and sunflower (2015-2016). 1 – ploughing; 2 – chisel treatment; 3 – surface treatment; and 4 – combined treatment;* - *rounded to integers.*

Despite the uneven range of variation under corn and sunflower, the same pattern was observed. In the 0-10 cm layer, the variation index increased (the leveling index decreased) in the following order - plowing, deep subsurface loosening, surface treatment, and in the 15-25 cm layer, it decreased in the same order. In the 30-40 cm layer, the variation index decreased (the leveling index increased) in the following order: deep subsurface loosening, surface treatment, plowing. In all cases, with the exception of the 15-25 cm layer under corn (for the 2015 crop, the method of treatment in the combined system was not established correctly), the smallest or closest variation was observed in the option with the combined treatment system.

As a whole, the variation increased (the leveling decreased) correspondingly to the negative effects of specific treatments on certain layers, which again demonstrates that it is of great importance to take into account physical ripeness of the soil.

4. Conclusion

Optimization of the parameters of the agrophysical state of the compacted chernozem in the cultivation of row crops is the basis for obtaining the planned crops. The treatment of physically ripe soil has a positive influence on the density, and it, in turn, promotes the soil porosity. The combined basic soil treatment system provides the approximation to the optimal parameters of the agrophysical state.

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