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Changes in Agrophysical Properties of Compact Chernozem Depending on the Soil Treatment Methods

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Abstract: The present work gives the results of the long-term field studies on determining optimal agrophysical properties of compact leached chernozems of heavy mechanical composition at different treatment methods. It was found out that with the increase of depth the process of differentiation of the studied soil thickness in terms of its density begins; the degree of the soil density in the low and middle parts of the 40-centimeter layer does not exceed the critical value; the density in the sowing soil layer is usually less than the optimal one; the degree of the soil density is mostly aligned with the soil moisture during its treatment than directly with the soil treatment methods; the differences due to the variants being studied are mostly found in the layer of 15-25 cm thickness during the physically unripe soil treatment.

Key words: Chernozem · Agrochemical properties · Soil density · Moisture · Optimal density

INTRODUCTION

The optimization of parameters of agrophysical condition of the soil provides the favourable state of the water-air, salt and heat regimes, as well as contributes to the activation of microbiological processes towards the enhancement of the nutrient status. The net result is that the value of the agrophysical indicators is significantly affects the yield capacity [1-7].

The studies on definition of the optimal agrophysical parameters of compact chernozems were held during 2005-2008 in the Adygei State Agricultural Research Institute of the Russian Agricultural Academy the land-use territory of which belongs to the zone of sufficient (although unstable) moistening.

The compact chernozems are the main soil covering of the plowed fields of the Adygei State Agricultural Research Institute of the Russian Agricultural Academy. According to the schematic soil map, they occupy about 78% of the whole territory. The composition of the physical clay (separates 0.01 mm) throughout the whole profile is quite high - up to 76% [5].

The soil specific weight (the weight of absolutely dry soil to its volume unit) is the key factor of the soil productivity. The optimality of this indicator differs depending on the type of the soil and its granulometric composition.

The most favorable conditions for the plants' growth are formed at the optimal soil density. Naturally the balanced condition between the solid body and porous body, which is also called the steady-state density, appears under the influence of compaction and dislodgement processes proceeded in the soil. The patterned soil has the minimal limit between the optimal and steady-state density, while at the well cultivated soils their values can match, as, for example, in chernozems [8].

The differential response to density of the feral cultivated plants became a well-known fact due to the extensive studies of this issue [9-11].

For the same cultures but on the different soils the different values for optimal density were set (accepted). In this case the certain ideal value is not stated, but the most close to the optimum and realizable on certain soils value is indicated.

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Main Part: The soil density condition should be estimated in the complex with other agrophysical and agrochemical indicators [11, 12]. The data of optimal (in the sense of approaching to the ideal) density of chernozems in the Central part of Krasnodar Krai for some of the cultures are given below in Table 1.

From the data given above we can see that for the compact chernozem the limit of the density achievable for the fix of the best conditions relating to the sugar beet, corn and sunflower is moved onto 0.13-0.06 g/cm^3 in comparison with the leached chernozem. Thus we have made our studies of factors of the soil density optimization on the compact chernozems (Tables 2 and 3).

In the studies, the difference in the sowing layer density under the corn during the separate years is the following: in 2005 (the humid aforegoing fall) - 0.95-0.99 g/cm^3; in 2006 and 2007 - 1.05-1.07 g/cm^3 and 1.00-1.02 g/cm^3 respectively. In other words, the differences in conjunction with the types of experience (methods of the soil treatment) were inconspicuous.

The consolidation of layer of 15-25 cm thickness was noted in 2005 in the plowing treatment type. The highest density of the layer of 30-40 cm thickness was also noted in the same year.

At aboveground treatment the density of the layer of 15-25 cm thickness which was almost not induced by the cultivating equipment was the most optimal and the smallest one during the whole years of studies. But at the same time in the layer of 30-40 cm thickness it was at the plowing level.

The similar was the influence of the studied systems of the key methods of compact chernozem treatment under the sunflower: the low density of the higher slice at the practical lack of differences between the types of the treatment methods; the consolidation of the middle (at the plowing) and low (at chisel method of treatment) parts of the studied thickness of the soil; the smaller consolidation of the layer of 15-25 cm thickness at implementation of the aboveground method of treatment.

At the combined system the values of the density of the chosen methods of treatment have mostly matched with the values of the irremovable implementation of particular methods.

At the average, during the years of researches the density of the compact chernozem practically was more approximative to the optimal interval of values in the type of combined system of the soil treatment. Thus, if the predefined interchange of the soil key treatment methods

Table 1: The solid optimal density (g/cm^3) for the agricultural crops growth on the Kuban chernozems (generalized material) [13]

	Culture				
Type of soil	Fall wheat	Sugar beet	Corn	Sunflower	Lucerne
Leached chernozem	1.22-1.30	1.10-1.20	1.16-1.23	1.20-1.30	1.10-1.38
Typical 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	-

Table 2: The density of the soil under the corn depending on the main methods and systems of the soil treatment (g/cm^3).

		Year			
Types of the soil treatment key methods	Soil layer, cm	2005	2006	2007	Average
Plowing onto 25-27 cm (irremovably)	0-10	0.99	1.05	1.01	1.02
	15-25	1.33	1.19	1.24	1.25
	30-40	1.31	1.22	1.29	1.27
Chisel onto 38-40 cm (irremovably)	0-10	0.96	1.06	1.00	1.01
	15-25	1.26	1.22	1.19	1.22
	30-40	1.30	1.24	1.23	1.26
Aboveground onto 10-12 cm (irremovably)	0-10	0.95	1.07	1.02	1.01
	15-25	1.22	1.17	1.19	1.19
	30-40	1.28	1.23	1.29	1.27
Combined system of treatment	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 3: The density of the soil under the sunflower depending on the main methods and systems of the soil treatment (g/cm^3).

Types of the soil treatment key methods	Soil layer, cm	Year 2006	2007	2008	Average
Plowing onto 25-27 cm (irremovably)	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 onto 38-40 cm (irremovably)	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
Aboveground onto 10-12 cm (irremovably)	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 system of treatment	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

had no influence onto the soil density, the choice (the adjustment depending on the weather conditions) was more productive, which can be seen from Tables 2 and 3. Practically, almost every year and averagely during the years of plowing, the adjustable combination type showed the best soil density indicators: in the layer of 0-10 cm thickness it was a bit higher, while in the other parts of the 40-centimeter layer it was a bit lower in comparison with other types, except for the method of treatment which was chosen for the adjustment.

The soil porosity means the number of spaces free from the solid body of the soil expressed in percentage to the volume of the soil. Total porosity means the integral capacity of pores and spaces between the soil parts expressed in percentage to the volume of the soil. The total porosity is divided by the capillary (the narrower and not connected between each other spaces which contribute the relatively rapid move of the water) and non-capillary porosity. In the patterned soils such types of porosity are respectively called the internally-aggregate and externally-aggregate porosity. The sufficient amount of the non-capillary spaces makes conditions for the proper level of the soil gaseous interchange with the air and provides the better water encroachment which absorbs and delays in the capillary pores [11].

The total porosity value and the proportion of volumes of the non-capillary and capillary pores characterize the soil structure. The pattern soils have the well developed non-capillary and capillary porosity. In such soils even after the strong soil moistening the moisture stays inside the aggregate pores, while the interaggregate pores are occupied with the air. The simultaneous content of air and moisture in the soil creates the favorable conditions for the life of the plants' bases and aerobic microorganism providing the plants with the delivery of the nitrogenous and high-ash nutrition [14, 15].

The nonproductive consumption of water increases not only at the high capillary porosity (rapid ingress of evaporation to the surface), but also at the high non-capillary porosity by means of convective-diffusive way of evaporation due to the intensive gaseous interchange. According to the researches made by Kachinsky N.A. Poyasov N.P. Dolgov S.I. and Modina S.A. for the normal gaseous interchange between the soil and the atmosphere the availability of not less than 10-15% of the non-capillary pores (aeration pores) from the total volume of the soil at the total porosity of 50-60% is required.

As the porosity depends on the composition and texture of the soil (in the low horizons of the mineral soils it is about 35-45%, while in the plowing layer it can increase up to 55-70%; the high porosity have the soils rich in humus, the pattern soils (55-65%) and especially the peaty soils; the porosity of the soils poor on organic substances and the non-structural soils is about 40-45% and less), its values (including the correlation of the pores mentioned above) most favorable for the yielding capacity formation can vary depending on the soil-climate conditions [16, 17].

The compact chernozem in its natural features differs by the unfavorable close correlation of capillary and non-capillary porosity [11, 14], i.e. the increase of the total porosity simultaneously leads to the increase of its non-capillary part. At the total porosity of 55% the non-capillary exceeds the optimal value.

Taking into account the facts above stated and the lack of estimation scale, we have set the interval of the total porosity within limits of 58-52% as the most acceptable one which does not contradict the existing (distinct) estimations for the chernozem soils.

From the data given in Table 4 (the results of the studies under the corn) we can clearly see the significant differentiation on porosity between the higher and low slices towards the decrease from the first one (in most cases the value of porosity exceeds 60%) up to 57.3-48.7% in the layer of 15-25 cm thickness and 57.3-48.4% in the layer of 30-40 cm thickness. If the differences in the layer of 0-10 cm thickness in a view to the types of the made experience were inconspicuous, then in the deeper disposed layers the differences are more noticeable and they depend on the state of the soil mellowness during the period of the soil cultivation. Thus, in 2005 in the layer of 15-25 cm thickness the negative impact of the plowing was noticed - the porosity was 48.7% (also 50.0% for the combined system of treatment when the method of treatment in the mentioned year was chosen wrongly). At the chisel treatment method in 2005 the value of porosity was also low in the layer of 30-40 cm thickness which can also be explained by the depth of treatment at abundant rainfall during the previous fall.

During all years the most satisfactory and close in its size porosity was noted in the layer of 15-25 cm thickness in the aboveground method of treatment. Though we cannot consolidate the same concerning the lower third of the studied soil thickness where in 2005 the inexplicably low porosity was fixed.

In average, during the whole period of studies the better values were received at the combined system of treatment.

The results of porosity under the sunflower do not contribute to the received results under the corn: the similar contrast in the studied layers and the lack of differences in connection with the types of experience in the layer of 0-10 cm thickness are observed (Table 5).

The best values of porosity were received in 2006 on plowing, in 2007 at chisel method and in 2008 at aboveground method of treatment. As a result, on average for the years of studies the best results were achieved in the combined system of the soil treatment.

While processing the compact chernozem for the yield in 2008 the previous fall was wet. Due to this the decrease of the porosity in the layer of 15-25 cm thickness (49.2%) after the plowing and in the layer of 30-40 cm thickness (48.4%) after the chisel treatment was noticed. After the aboveground treatment the level of porosity was close to its optimal value, but at the low border of acceptable interval in the layer of 30-40 cm thickness, which is inexplicable from point of the cultivating equipment working tools influence.

It should be noticed that the values of porosity under both cultures in the type of combined system of treatment have practically coincided with the values in those types of treatment methods which were taken at combined system of the soil treatment.

We gave no data on correlation of interaggregate and intergranular pores due to the fact that the part of non-capillary pores was much more significant than it is required for the normal gaseous interchange process

Table 4: Total porosity of compact chernozem under the corn depending on the main methods of the soil treatment (%).

		Soil layer, cm		
Types of the soil treatment key methods	Year	0-10	15-25	30-40
Plowing onto 25-27 cm (irremovably)	2005	64.9	48.7	52.6
	2006	63.7	55.0	57.3
	2007	59.6	49.9	55.1
	Average	62.7	51.2	55.0
Chisel onto 38-40 cm (irremovably)	2005	66.6	52.0	48.4
	2006	59.9	57.3	55.2
	2007	57.7	52.4	57.6
	Average	61.4	53.9	53.7
Aboveground onto 10-12 cm (irremovably)	2005	66.8	53.1	49.3
	2006	54.2	52.8	52.5
	2007	62.0	54.6	56.6
	Average	61.0	53.5	52.8
Combined system of treatment	2005	63.2	50.0	52.7
	2006	57.0	56.1	55.9
	2007	57.5	53.7	56.7
	Average	59.2	53.3	55.1

Table 5: Total porosity of compact chernozem under the sunflower depending on the main methods of the soil treatment (%).

		Soil layer, cm		
Types of the soil treatment key methods	Year	0-10	15-25	30-40
Plowing onto 25-27 cm (irremovably)	2006	62.1	57.4	56.0
	2007	64.1	54.5	55.8
	2008	64.6	49.2	53.5
	Average	63.6	53.7	55.1
Chisel onto 38-40 cm (irremovably)	2006	64.0	52.6	53.0
	2007	60.7	56.9	58.5
	2008	61.3	50.7	48.4
	Average	62.0	53.4	53.3
Aboveground onto 10-12 cm (irremovably)	2006	65.6	52.8	53.0
	2007	65.0	55.5	54.2
	2008	60.5	54.0	50.3
	Average	64.5	54.1	52.5
Combined system of treatment*	2006	62.9	53.7	54.0
	2007	60.8	56.5	56.2
	2008	59.9	54.8	52.7
	Average	61.8	55.0	54.3

*at the combined system of treatment during the previous to the given above years fall the results are the following: 2006 - plowing, 2007 and 2008 - chisel and aboveground treatments.

and was equal to almost half of the total porosity. However, the correlation of capillary and non-capillary interspaces due to the methods of the soil key treatment was not equally unfavorable. In RK Tuguz researches [14] the number of capillary pores in the layer of 15-25 cm thickness was by 7-14% more at the chisel treatment than at the plowing method.

Key Takeaways: The present researches have stated the following: 1) the differentiation of the studied thickness of the soil in density which increases with the depth; 2) the value of the soil density in the middle and low parts of the 40-centimeter thickness layer did not exceed the maximal (critical) values; 3) the density of the sowing layer of the soil is usually less than the optimal one; 4) the value of the soil density is mostly connected with the soil moisture during its treatment (as well as the structure of the soil) than directly with the treatment methods; 5) the differences in conjunction with the studied types of the soil treatment were mostly found in the layer of 15-20 cm thickness at the physically unripe soil treatment.

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