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The influence of soil protection technologies on the content of organic substance in leached chernozem

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Abstract. The quantitative content of organic carbon and mobile organic matter, its share in the total organic carbon is estimated. A significant intraseasonal variation of organic carbon was revealed when using dump processing. For the first time, the long-term impact (9-10 years) of soil protection technologies on the dynamics of organic carbon content and its mobile forms was determined for the agricultural zone of the Krasnoyarsk territory. It is shown that the zero land treatment reduces the degree of mobility of organic matter, and the minimum treatment (disk plowing) causes a significant differentiation of the seed 0-5 cm and the underlying 5-20 cm layer according to the content of sorghum.

1. Introduction

Agronomic factors affect the concentration of organic carbon in the soil. Its degradation contributes to a significant loss of land fertility. One of the most important structural characteristics of soil organic matter is the mobile organic matter. The share of soil protection technologies in the agricultural systems of the Krasnoyarsk territory has been increasing recently, and information on the dynamics of mobile organic matter and its components in the soil, when using these influences, is not given enough [1]. Often it is contradictory and does not have a systemic nature. The practical problem of research is the reduction of mobile organic matter in agricultural soils due to its plowed-out condition of the classical dump methods of processing usage [2].

The aim of the article is to estimate the parameters of the content of organic carbon and mobile organic matter in the soil treated by the dump method, as well as by the type of minimum and zero land treatment. Research questions:

- To assess the intraseasonal dynamics of the studied organic compounds of leached chernozem;
- To determine the content of endohumus and alkaline-soluble organic compounds in the studied soil layers;
- To carry out the role of various factors in the variability of soil organic matter in different processing technologies.

2. Materials and methods

The studies were carried out on the production experience of "Shilinskoye" in the Krasnoyarsk forest-steppe, located within the Chulym-Yenisei denudation plateau of the southwestern outskirts of Central

Siberia (56037’ N latitude and 93012' E longitude). The experiment was started in 2006. The object of research is the chernozem which is leached, medium humic, medium-power, strongly truncated, slightly clay soil based on red-brown clay. The scheme of the experiment is presented by the following options (methods of soil treatment): 1. Dump (st); 2. Minimum; 3. Zero.

Morphological description of soil profile cut sections on the territory of the field station in the experiment variants:

Section 1 is laid on the base area in the conditions of dump processing:

Apach 0-20 cm – black, fresh, light loamy, butty, fine-pored, no crack, lumpen, root channels, dendrites, does not bubble up, the transition is gradual;

AB 20-44 cm – brown, fresh, light loamy, butty, fine-pored, no cracks, lumpen, pith fleck, does not bubble up, the transition is gradual;

B 44-70 cm – ochre-brown, fresh, clayed, butty, fine-pored, no cracks, lumpen, does not bubble up, the transition is clear;

VS_K 70-100 cm – red-brown, heavy clay-loam, very butty, fine-pored, no cracks, bubbles up

Section 2 is laid on the base area with the use of minimum land treatment:

A 0-65 cm – black, moist, medium-loamy, butty, fine-pored, lumpen-nutty, humus substances, root channels, does not bubble up, tongued transition;

AB 65-83 cm – dark brown, moist, heavy-loamy, butty, fine-pored, thin fissured, lumpen, few roots, does not bubble up, the transition is gradual;

VS_K 83-100 cm – brown, moist, clayed, butty, fine-pored, nutty, inclusions no;

The soil of the experiment is characterized by: humus content - 5.9 %, neutral reaction of the medium (pH2O = 6.8). The total absorbed bases ranges from 60 to 62 mg-EQ / 100 g of soil. Hydrolytic acidity varies from 0.2 to 0.6 mg-EQ / 100 g of soil. The degree of saturation of the bases is 99 %.

During the growing season of 2013, the land, where the zero land treatment processing was used, was in the conditions of chemical fallow. Here, a three-time treatment with a tank mixture of herbicides "Topic" and "Cowboy", fungicide "Alto Super" and insecticide "Karate" was carried out. In the third decade of August, winter triticale was sown by the SS-6 combined assembly unit without preliminary soil preparation with mechanical seed sowing. Its crop season was in 2014. During the next 2015year, the crops were represented by spring wheat.

The minimum soil preparation was carried out by SCS-3,2. With the help of disk horizontal gouters of the sowing complex, soil cultivation to a depth of 4-5 cm was carried out. Grain crops were sown with simultaneous introduction of ammonium nitrate phosphate fertilizer (in 2014 – spring wheat, in 2015 – winter triticale).

The "standard" (dumped) main treatment consisted of underwinter plowing to a depth of 20-22 cm and spring cultivation. Sowing of spring wheat in 2013-2015 was carried out by a combined assembly unit - a stubble seeder SS-6 with simultaneous application of ammonium nitrate phosphate fertilizer at seeding.

The period of validity of soil protection technologies at the beginning of our observations was nine years.

Within the production crops base area of 500 m^2 elongated shape was allocated. Three times during the growing season soil samples were taken from layers 0-5 and 5-20 cm by the “like-snake” method. The sample size (n = 15) was calculated based on the value of soil fertility variation determined before the experiment.

In the years of observations, the distribution of heat and moisture was characterized by the following parameters (table 1).

During most months of the warm period of 2014, moisture was slightly increased relative to the average years-long norm. The maximum amount of precipitation fell only in July - 89 mm. Such combination of heat and moisture causes sufficient watering during the growing season of field crops. According to G. T. Selyaninov, the value of hydrothermal coefficient (HTC) for June-August was 1.3.

Table 1. Meteorological indicators in years of observation.

Year	Month					Sum over the growing season
	May	June	July	August	September	
	Mean air temperature, ^0C					
2014	6,8	16,0	19,2	15,9	6,5	1565
2015	10,9	17,0	19,9	16,5	8,4	1535
Norm(1980-2010 yr.)	8,7	15,5	18,3	14,9	8,3	1627
	Precipitation, mm					
2014	53,5	50,4	89,4	74,9	32,4	300,6
2015	30,9	32,6	68,5	62,9	73,4	268,3
Norm(1980-2010 yr.)	34,7	46,8	64,5	58,6	42,5	247,0

The beginning of the crop season in 2015 was characterized by higher temperatures in comparison with the previous season and further to the autumn; the average monthly values exceeded the parameters of 2014. On the contrary, the amount of precipitation inferiors to last year significantly. The value of HTC for the period of active vegetation was 1.0. Thus, the conditions of the crop season of 2015 were estimated as more drought in comparison with the season of 2014.

Chemical and physical and chemical parameters are obtained according to the generally accepted prescriptions of modern methods [3]. The average laboratory soil sample was evenly distributed on paper with a layer thickness of about 5 mm. The large structural units or individually pre-crushed with a pestle in a pounder. Then the soil was distributed on paper and divided into squares with a side of 3-4 cm, drawing vertical and horizontal lines with a spatula.

From each square to the entire depth of the layer, a small amount of soil was taken with a spatula and placed in a bag of tracing paper. The weight of the soil sample was 3 g. The roots and other organic debris were not removed from the analytical soil sample. Next, the soil was sifted through a sieve first with holes of 1 mm, then - 0.25 mm. Soluble in alkaline medium organic matter is heterogeneous, has a difficult to recognize structure, representing a conglomerate of individual compounds, destroyed condensed formations and organomineral complexes.

In the prepared samples, the content of organic (SORG) and alkaline-soluble carbon (C0, 1NaOH) was determined by I. V. Tyurin in the ratio of 1:5 and 0.1 n NaOH in the ratio "hitch : extragent" = 1: 20 [4]. In soil samples were determined: pH of aqueous and saline suspensions – by potentiometry, hydrolytic acidity by Kappen, total exchangeable bases – titrimetric by Kappen-Gilkowitz in modification of Hodline, the base exchange capacity and degree of base saturation – by calculation method. At the same time, soil samples were taken for moisture by means of a hole borer in layers. Humidity was determined by thermostatic-weight method. The aggregate-size distribution of soil was determined by the pipettor method according to N. A. Kachinsky [5]. Terms of soil samples selection are timed to the main phases of development of agricultural crops.

3. Results

Let's consider how the organic carbon of the soil was distributed in the variants of the experiment in dynamics (table 2).

When using dump processing in the upper layer there was a significant increase in the content of organic carbon of the soil from June to September (table 3). What is the meaning of this information? Probably, during the growing season of spring wheat from the spring to the crop period in the twenty-centimeter layer, conditions for the accumulation of organic carbon were formed. First of all, it is necessary to recall the weather situation developing during this period (see table 1). Cool May and early June did not contribute to the production of organic matter. Further, apparently, during the growing season of spring wheat, the soil was replenished with mortmass, detritus and root secretions. The level of spatial variation in the area treated with the dump plow was negligible, especially at the beginning of the season.

Table 2. The statistical parameters of sorghum content and dynamics (mg / 100 g) in leached chernozem (2014).

Variants	Timing	Layer	M*	SD	s_X	V,%	M±ts_x
Moldboard plowing	June (1)	0-5	2854	79	21	3	2854±46
		5-20	2925	84	22	3	2925±49
	July (2)	0-5	3686	538	143	15	3685±310
		5-20	4171	255	68	6	4171±147
	September (3)	0-5	4614	543	140	11	4614±300
		5-20	4662	507	131	11	4662±281
Minimum land treatment	June (1)	0-5	4153	470	126	11	4153 ±271
		5-20	3952	609	162	15	3952±351
	July (2)	0-5	4126	338	90	8	4126±195
		5-20	4230	442	118	10	4230 ± 255
	September (3)	0-5	4363	317	81	7	4363 ±175
		5-20	3894	446	115	11	3893±247
Zero land treatment	June (1)	0-5	2462	370	98	15	2462 ± 213
		5-20	2406	378	101	16	2406 ± 218
	July (2)	0-5	3380	386	100	11	3379 ± 213
		5-20	3785	486	126	13	3785 ± 269
	September (3)	0-5	2636	367	98	14	2636 ± 211
		5-20	2493	386	103	15	2493 ± 223

* M – medium, SD – standard deviation, sX – sample error, V – coefficient of variation, ± ts_x – confidence interval

In the soil of the variant cultivated with disk horizontal gouters (minimum land treatment), the content of organic carbon was characterized by high values in comparison with the soil where moldboard plowing was used. However, the nature of the intraseasonal dynamics here was assessed as more stable. Probably, loosening of only the surface layer in the observed soil-hydrothermal conditions contributed to less variability of soil organic carbon transformations.

Table 3. Statistical significance of intraseasonal dynamics of SORG (2014).

Variants	Timing	0-5 sm	5-20 sm
Moldboard plowing	June (1)	$\mathbf{t_1t_2 > t_{0,5}}$	$\mathbf{t_1t_2 > t_{0,5}}$
	July (2)	$\mathbf{t_1t_3 > t_{0,5}}$	$\mathbf{t_1t_3 > t_{0,5}}$
	September (3)	$\mathbf{t_2t_3 > t_{0,5}}$	$\mathbf{t_2t_3 > t_{0,5}}$
Minimum land treatment	June (1)	$t_1t_2 < t_{0,5}$	$t_1t_2 < t_{0,5}$
	July (2)	$t_1t_3 < t_{0,5}$	$t_1t_3 < t_{0,5}$
	September (3)	$\mathbf{t_2t_3 > t_{0,5}}$	$t_2t_3 < t_{0,5}$
Zero land treatment	June (1)	$\mathbf{t_1t_2 > t_{0,5}}$	$\mathbf{t_1t_2 > t_{0,5}}$
	July (2)	$t_1t_3 < t_{0,5}$	$t_1t_3 < t_{0,5}$
	September (3)	$\mathbf{t_2t_3 > t_{0,5}}$	$\mathbf{t_2t_3 > t_{0,5}}$

* here and below: bold indicates significant differences between observation periods

The application of zero land treatment for nine years, as can be seen from table 2, had a negative impact on the carbon content of organic matter in both analyzed layers. Dynamic changes in organic carbon in untreated soil were expressed reliably with a maximum in mid-summer. Next, we consider whether the revealed patterns in the dynamics of organic carbon in the soil of variants in the 2015 season were manifested.

Table 4. Statistical parameters of sorghum content and dynamics (mg / 100 g) in leached chernozem (2015).

Variants	Timing	Layer	M	SD	s_X	V,%	$x \pm ts_x$
Moldboard plowing	June (1)	0-5	5119	413	106	8	5119±228
		5-20	5003	534	138	11	5003±296
	July (2)	0-5	4157	555	143	13	4157±307
		5-20	4019	609	157	15	4019±337
	September (3)	0-5	4804	546	141	11	4804±302
		5-20	4540	433	111	10	4540±239
Minimum land treatment	June (1)	0-5	4440	477	123	11	4440 ± 264
		5-20	4056	312	80	8	4056±172
	July (2)	0-5	4678	513	132	11	4678±284
		5-20	4467	390	101	9	4467 ± 215
	September (3)	0-5	4371	361	93	8	4371 ±200
		5-20	3905	479	123	12	3905±265
Zero land treatment	June (1)	0-5	2407	458	118	19	2407 ± 253
		5-20	2291	350	91	15	2291 ± 194
	July (2)	0-5	3232	389	100	12	3232 ± 215
		5-20	3497	467	121	13	3497 ± 258
	September (3)	0-5	2571	279	72	10	2571 ± 154
		5-20	2575	349	90	13	2575 ± 193

Weather conditions in 2015 were very different from the previous season. The first half of summer was characterized by significantly less precipitation, and the thermal regime of the whole season was almost more than the norm in terms of heat (table 1). Thus, the intraseasonal modification of organic carbon is subject to cyclicality. The results of the two-factor dispersion analysis showed that the greatest impact on the variability of organic carbon from the studied factors was exerted by the parameter "Processing Options " (table 5).

Table 5. The assessment of the contribution of factors to changes in organic carbon content (two-factor analysis of ANOVA).

Factor	Impact indicator (II), %			
	2014		2015	
	0-5 sm	5-20 sm	0-5 sm	5-20 sm
Processing options	47	35	72	61
Timing	13	20	0	2
Interaction	19	22	10	16
Factors not taken into account in the experience	21	22	18	20

In 2014, the influence of this factor was significantly higher in comparison with the influence of parameters that cause the dynamics of organic matter and their interaction. This pattern was manifested in both studied soil layers. Consequently, changes in agrophysical parameters have a greater impact on the conversion of organic carbon. It should be emphasized that these transformations can vary not only directly due to loosening, but also with the fluctuation of conditions depending on the level of arable impact. These may include: the level of humidity, the concentration of the root system network, its qualitative composition, and the degree of aeration. It is also known that the labile fraction of organic carbon plays a crucial role in the formation of aggregates and responds quickly to changes in the farming system due to the short turnaround time [6]. However, all of the above also changes in dynamics, when you change the dates of the calendar. In our opinion, the greater contribution of the factor "Processing Options" is associated with a more complex and fundamental influence of processing technologies on soil processes. In the following season, the level of influence of the soil treatment method increased significantly, and the "timing" was almost not involved in the variability of soil organic matter carbon concentrations.

Agronomic science has established that during the growing season there is a differentiation of the plowing layer by fertility [7]. Therefore, when theoretically justifying soil treatment systems in crop rotation fields, it is necessary to take into accounts this phenomenon and, especially, when choosing technological operations: inversion, mixing, depth of treatment, etc. [8]. Consider how the nine-ten year period of soil protection technologies affected the differentiation of the compared soil layers according to the content of organic carbon in them (table 6). During 2014, significant differences between the layers in the level of sorghum during dump treatment were expressed in June-July. It should be noted that the highest content of sorghum in this type of processing was observed in the layer of 5-20 cm relative to 0-5 cm layer. This is probably due to the embedding of plant residues in the lower layers of the soil, which contributed to an increase in the share of sources of humification and, possibly, slowing down the processes of mineralization.

Table 6. The adequacy of differences (t) in the content of sorghum in the compared layers t 0,5= 2.14.

Variants	2014					
	June		July		September	
1. Moldboard plowing	**-3,2**	2857 2929	**-3,2**	3654 4104	- 0,5	4615 4662
2. Minimum land treatment	**2,2**	4190 3969	-0,9	4128 4231	**5,6**	4363 3894
3. Zero land treatment	0,7	2462 2396	**-2,5**	3380 3785	1,4	2641 2470

With minimal soil treatment, the inverse relationship was observed. The greatest amounts of sorghum were observed in the layer 0-5 cm in relation to the underlying layer in June and September. It should be noted that a large difference in the content of sorghum in layers 0-5 and 5-20 cm was revealed in September, and this month the content of sorghum in the layer 0-5 cm was the maximum for the entire analyzed period. Since crop residues are the main source of organic carbon in the soil, it was noted that with minimal processing, the bulk of crop residues was in the layer 0-5 cm. This is due to the peculiarities of soil cultivation to a minimum depth. With zero land treatment, significant changes in the content of sorghum were noted only in July. The increase in the concentration of organic carbon in the soil in mid-summer contributed to the increase in biomass of crop residues on the soil surface with this method of soil treatment.

At the same time, there were no significant differences in the early summer and autumn.

In 2015, in contrast to the previous season, in the conditions of dump treatment, it was not possible to identify significant differences in the content of sorghum between the compared layers (table 7). With minimal soil treatment, there were significant differences in the content of sorghum, as in 2014, and the values are reliable for the entire observation period. The highest content of sorghum in this type of treatment was observed in the layer 0-5 cm in relation to the layer 5-20 cm. The highest value in the content of sorghum with minimal soil treatment was observed in July in the layer 0-5 cm.

An interesting regularity was found when comparing the concentrations of organic carbon using zero soil treatment. For two years of observations in the middle of summer (in July), significant differences between layers were found, and with maxima in the layer of 5-20 cm. This fact probably indicates a significant influence of plant root systems in the accumulation of carbon of organic matter during the period of their greatest production. Taking into account the absence of mechanical loosening, warm weather, maxima of root exudates, it becomes obvious that sorghum at zero soil treatment is actively formed not only in the surface layer.

Table 7. The adequacy of differences (t) in the content of sorghum in the compared layers (t0, 5= 2.14).

Variants	2015					
	June		July		September	
1. Moldboard plowing	0,7	5119 5003	1,8	4156 4020	1,7	4804 4540
2. Minimum land treatment	2,7	4440 4056	2,3	4678 4467	5,4	4372 3906
3. Zero land treatment	1,2	2407 2291	-2,2	3232 3497	-0,0	2572 2575

4. Summary

The dump method of soil treatment contributes to a more significant intraseasonal dynamics of soil organic carbon.

The greatest contribution to the change of organic carbon of leached chernozem is made by the "Processing Options" factor.

Dump processing of soil treatment does not cause significant differentiation of the plowing layer, and in some periods accumulates significant amounts of sorghum in a layer of 5-20 cm, relative to the top layer. The use of minimal treatment, on the contrary, contributes to a significant difference between the compared layers in the content of sorghum with the maxima in the surface layer.

The content of mobile organic matter in the soil treated by the dump method and surface disking is estimated at the same level. The use of zero land treatment significantly reduced the concentration of C0, 1NaOH and the degree of its mobility.

Intraseasonal changes of alkali-soluble carbon were characterized by significant fluctuations in the conditions of dump and minimum treatment. The use of zero land treatment contributed to the stabilization of the content of C0, 1NaOH during the field season. Spatial variation of mobile forms of organic compounds was estimated as high.

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