Humus substances content in agrochernozems using for cultivation of oilseeds in the Kansk forest-steppe

O A Vlasenko, N L Kurachenko, O A Ulyanova, V V Kazanov and F Kh Khalilzoda
Krasnoyarsk State Agrarian University, 90 Mira ave., Krasnoyarsk, Russian Federation
E-mail: ovlasenko07@mail.ru

Abstract. The agrochernozems of the Kansk forest-steppe used for the cultivation of rapeseed and camelina were characterized by a high humus content both in the 0–20 and 0–40 cm layer. The carbon content of humus (C_humus) and carbon of water-soluble organic matter (C_H2O) had a weak spatial variability (Cv = 1.3-11.7%), the content of carbon extracted with 0.1 n alkali (C0.1 n NaOH) had an average and very high degree of spatial variability (Cv = 18.7-66.1% ) The heterogeneity of the soil cover was a factor determining the average statistical decrease in the content of stocks of all fractions of humic substances, with the exception of water-soluble carbon of humus. Fields with a pronounced meso- and microrelief and the presence of thinner types of agrochernozems are recommended for use for the cultivation of camelina, as a crop less demanding on soil conditions than rape.

1. Introduction
Soil organic matter is one of the main parameters of fertility and is characterized by a complex, heterogeneous structure and many functions. Some humic substances are loosely bound to the soil matrix, chemically unprotected and easily accessible for decomposition; this is an active pool of humic substances, which is represented by undecomposed plant and animal residues, microbial biomass and organic matter of light particle size fractions, non-aggregated and inter-aggregate organic matter, and carbon compounds extracted with water and salts and alkalis [1, 2].

Studies [3, 4, 5] confirm that in water soils both water-soluble and alkali-hydrolyzable organic matter together form a mobile or mobile pool of organic substances, performing the structure-forming function and the function of a high-energy food source for heterotrophic microorganisms, supporting soil biological activity and mineralization processes as a result of which nutrients for plants are released, providing effective soil fertility

2. Conditions and objects of research
The study was conducted in 2019 in the land use of OPK Solyanskoye LLC in the Kansk forest-steppe of the Kansk-Rybinsk geomorphological district. On two plots of arable land for grain-crop rotation of 5 ha each, the humus state of the soil was studied before sowing rapeseed and camelina cultivated on oilseeds. The preceding crop is a pea-oat mixture. The soil cover of the territory is closely related to the relief conditions. Key site No.1 (56°005′ N and 95°053′ E) is characterized by a wide-dumped relief with a weakly pronounced microrelief in the form of small depressions and various-shaped elevations, which is typical for most of the Kansk forest-steppe. The structure of the soil cover of this site is dominated by agro-black earth-clay-illuvial typical medium-powerful and powerful. Different types of
agrochernozems of clay-illuvial podzolized agro-chernozems are found by barely noticeable microdepressions. The key site No. 2 (56°025ʾN and 95°242ʾE) is located on the gentle slope of a wide uval stretched from west to east. Trial plots are laid on the elevated part of the slope, the middle, gentle and lower, where the micro-depressions are more pronounced. This site is distinguished by the greatest complexity of the soil cover and is represented by a combination of clayey-illuvial agro-chernozems of typical different types, clay-illuvial podzolized agro-chernozems and cryogenic-micellar low-power agro-chernozems occupying micro-elevations.

3. Research methods
To determine the classification of soils, the “Classification and Diagnostics of Russian Soils” was applied [6]. Soil sampling was carried out on 10 test plots from a depth of 0–20 and 20–40 cm. The samples were determined by addition density according to Kachinsky [7], humus by Tyurin (Сmuş), carbon of water-soluble organic matter (CH₂O) using the bichromate oxidation method alkali-hydrolyzable carbon of humus (С₀.₁н NaOH) and its composition contains humic carbon (Сha) and fulvic acid carbon (Сfa) in the decynormal alkaline extract according to Tyurin in the modification of Ponomareva and Plotnikova [8]. The results were processed by analysis of variance and descriptive statistics.

4. Research results
The total carbon content of humus (Сmuş) in chernozems was high and ranged from 3.5 to 4.2%. Statistical parameters show a weak degree of its spatial variability, both in the radial and in the lateral direction, which does not exceed 10 - 12% (Table 1).

| Key plot | Depth cm | Statistical parameters * | Сmuş | СH₂O | С₀.₁н NaOH | Cха | Cfa |
|----------|----------|--------------------------|------|------|------------|-----|-----|
| Number 1 | 0-20     | X                        | 4.2  | 0.021| 0.201      | 0.198|
| Rape (n = 10) |          | Sx | 0.2 | 0.001| 0.019 | 0.051|
|          | 20-40    | X  | 4.2 | 0.021| 0.18  | 0.254|
|          |          | Sy | 0.2 | 0.001| 0.049 | 0.028|
|          |          | Сv, % | 8.3 | 10.0 | 18.7  | 51.1 |
| Number 2 | 0-20     | X  | 3.9 | 0.019| 0.092 | 0.084|
| Ginger (n = 10) |        | Sx | 0.5 | 0.001| 0.030 | 0.025|
|          | 20-40    | X  | 3.5 | 0.019| 0.067 | 0.119|
|          |          | Sy | 0.4 | 0.004| 0.001 | 0.037|
|          |          | Сv, % | 8.9 | 4.3  | 36.0  | 66.1 |

* -X- medium, Sx- standard error of the mean; Сv, % - the coefficient of variation.

The relative error is from 1 to 5% of the average value. Thus, despite the combination of various subtypes of agrochernozems in a small area, the studied soils are quite homogeneous in terms of carbon content of humus. In the soil layer of 20-40 cm, the carbon content of humus is slightly lower than in the overlying layer, but it is also rated as high. This is a positive factor for growing crops and provides a deeper penetration of their roots.

Among the factors that have a significant impact on the humus content in chernozems, the most important factor is “A”, which is associated with the severity of the microrelief and the thickness of the humus horizon, the influence force in this case exceeds 34% (Table 2).

In the first key area, where the areas of medium-sized and powerful types of agro-chernozems dominate in the structure of the soil cover, the humus content is significantly higher than in the second
area with high complexity of the soil cover, pronounced microrelief and the prevalence of low-power species.

Table 2. The strength of the influence of factors on the carbon content of humic substances in agrochernozems, %

| Factor                  | $C_{humus}$ | $C_{gross(val)}$ | $C_{H2O}$ | $C_{0,1 \& NaOH}$ |
|-------------------------|-------------|-----------------|-----------|-------------------|
| Key Area (A)            | 34.1*       | 23.8            | 50.9*     | 45.0*             |
| Depth cm (B)            | 4.1         | 2.9             | 2.0       | 6.2               |
| Interaction (A + B)     | 5.2         | 6.0             | 0.03      | 0.3               |

* - the influence of the factor is reliable (p-value <0.05)

The content of organic matter (CH2O) extracted by the aqueous extract of carbon in the studied chernozems was low (0.019 - 0.021%), this is due to the fact that CH2O is characterized by an increased ability to mineralization and migration. The value of the coefficient of spatial variation of CH2O is estimated to be low, possibly due to the fact that by the time of sampling at the beginning of the growing season, fresh portions of plant residues were absent in the soil that could locally stimulate decomposition processes and increase the heterogeneity of the content of low molecular weight and easily soluble organic decay products in the soil [9, 10].

Spring rape (*Brassica napus* oleifera annua, Metz.d.)

Camelina (*Camelina sativa* (L.) Crantz)

Figure 1. The structure of carbon stocks of humic substances in agrochernozems: Cstabil. – carbon of stable humus; CH2O – carbon of water soluble humus; C ha – carbon of humic acid; C fa – carbon of fulvic acid.
In the composition of alkali-hydrolyzable organic matter of chernozems, the carbon content of humic acids ranged from 0.011 to 0.279%. The coefficient of variation was medium and very high and amounted to 19 - 67%. An increase in spatial heterogeneity and a significant decrease in the C$_{ha}$ content were noted in the second key area, this is due to the significant complexity of the soil cover and a decrease in the thickness of the humus horizon. A similar pattern can be observed in the carbon content of fulvic acids in soils. If in the first section with improved relief and more homogeneous soil cover, the C$_{fa}$ content was from 0.101 to 0.335%, then in the second section with a pronounced finely-deep-tuberous microrelief with heterogeneity of thickness and transitions of the humus horizon, the SFC content significantly decreased to 0.025 - 0.229%.

We found no statistically significant changes in the content of Cha and Cfa with depth due to the high variability of these indicators. Although the trend of a higher content of young humic acids in the upper soil layer, and young fulvic acids in the soil layer of 20-40 cm, is observed both in the first and second key sections, that is, it is independent of the microrelief and heterogeneity of the soil cover.

The amount of carbon reserves represented by water-soluble and alkali-hydrolyzable products in the soil layer of 0-40 cm was from 6.6 to 13.3 t/ha (figure 1), their share in the composition of $\Sigma_{gumus}$ ranged from 5 to 11%. Similar results were obtained on leached heavy loamy chernozems in crop rotations with clean steam without fertilizers [11].

The share of stable humus carbon in the studied chernozems was 89–95%. A high proportion of stable forms of humus in the structure of organic matter of arable chernozems indicates a high degree of agrogenic load and a deficiency in the supply of plant residues to the soil [12]. The cultivation of highly productive cabbage oilseeds will increase the intake of plant residues into the soil both during the growing season due to the partial death of the aboveground organs of plants and after harvesting of seeds due to crop residues and powerful root systems of plants.

In addition, it can be noted that, despite the high humus content of the soil, the humus reserves in the 0-20 cm layer turned out to be average, this is due to its physical state, which is characterized by a low density of addition, which is due to high humus content, good structure and long-term stay in the frozen state. The density of 0–20 cm of the layer of cultivated soils of key areas was estimated at an average value of 0.76 g / cm$^3$ with small and insignificant variability within the field (Cv = 9–15%). In the subsoil layer, it increased by 0.06-0.07 g/cm$^3$, while maintaining the loose structure.

5. Conclusion
The agro-chernozems of the Kansk forest-steppe, having a heavy particle size distribution, are characterized by a high humus content and its average reserves due to loose composition. Quantitative estimates of the content and spatial distribution of humus and its mobile compounds in agrochernozem were determined by the nature of the field topography and the features of the structure of the soil cover.

The complex of clayey-illuvial clay agro-chernozems typical, clay-illuvial podzolized clay and illuvial cryogenic-micellar gently sloping agro-chernozems with a decrease in the content and reserves of humic substances determined the increase in the heterogeneity of their spatial distribution. Fields with a pronounced meso- and microrelief and the presence of thin species of agrochernozems are better used for the cultivation of camelina, as a crop less demanding on soil conditions than rapeseed.

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