Biological factor of humus reproduction in conditions of the steppe zone of the Southern Urals

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Abstract. The paper considers a biological factor affecting the reproduction of humus and the maintenance of soil fertility in a region with unstable moisture. In the steppe zone of the Southern Urals, the humus formation process is affected by the amount of plant (stubble-root) residues entering the soil, which suggests the possibility of reducing the mineral fertilizers use. The purpose of the experiment was to determine the affecting of a set of field crops in crop rotations on the input of organic matter into the soil of the southern chernozem. The paper studies three variants of the experiment with different types of fallow. An increase of humus in the soil by 0.17% (in the percentage) was found in the crop rotation with fallow occupied by the summer sowing of Sudanese grass in comparison with grain-fallow with weed-free fallow. On average over 10 years, the largest volume of organic matter entered the soil during the cultivation of winter rye in a crop rotation with weed-free-fallow (11.87 tons per 1 ha).

1. Introduction
The most important criterion for the sustainability of an agroecosystem is soil fertility in the biological regulation of organic matter in the soil, expressed as a percentage of humus [1]. The use of land in modern agriculture leads to a deterioration in the physical, agrochemical properties, the structural state of soils and a decrease in the humus content during intense erosion processes, which leads to the degradation of chernozems [2, 3].

The intensity of the humus formation process depends on the volume of organic matter that entered the soil in the form of plant, stubbles and root residues, as well as the use of organic and mineral fertilizers [4, 5].

All over the world, the use of plant residues is considered as one of the sources for organic matter reproduction while maintaining functional soil properties in agrocenosis. The compliance of crop rotations helps to reduce or stop the degradation process and optimize the humus content in the topsoil [11].

The use of the stubble-root mass of plants leads to an increase in the content of organic carbon and nutrients in the soil, which implies a decrease in the proportion of fertilizers in the mineral form [12].

A huge role of organic plant residues in the carbon cycle is noted by many foreign authors in their papers [13-16].

Entering the soil, plant residues form an intermediate decomposition product, i.e., detritus. It is a source of nitrogen and other nutrients for plants and microorganisms, which can be easily mineralized.
and humified. It is necessary to take into account the content of detritus and characterize the humus state of the soil [19].

The study of the crops influence is important in the steppe zone of the Southern Urals because of crop rotations and their links on the entering of organic matter into the soil, as a biological factor of reproduction and maintaining the balance of humus with a steady increase in yield.

The purpose of the study is to determine the influence of crop rotations and to find crops necessary for the stabilization of organic matter in soils in the steppe zone of the Southern Urals.

2. Material and research methods

The object of the study is crop rotations and cultivated field crops, as well as the organic matter after harvesting residues in the form of stubble, root, straw, etc. The experiment was carried out in the central zone of the Orenburg region in a field long-term station for crop rotations of the Federal State Budgetary Scientific Institution of the Federal Scientific Center for Biological Systems and Agricultural Technologies of the Russian Academy of Sciences (FGBNU FSC BST RAS), with coordinates 51.775125 degrees North, 55.306547 degrees East.

The experimental plot of land is located on southern chernozem with medium-thick carbonate heavy loamy texture with a content of 3.2-4.0% humus in the arable (0-30 cm) soil layer, 0.20-0.30% total nitrogen, 1.5-2.5 mg phosphorus forms available for plants, and exchangeable potassium 30-38 mg per 100 g of soil. The pH of the reaction of the soil solution is pH = 7.0-8.1 (neutral - slightly alkaline).

The average annual climatic precipitation rate is 250 mm. The snow cover in winter reaches 0.5 meters, the soil freezes to a depth of 0.6-0.8 m.

The experiment was carried out in four replicates with a systematic arrangement of variants in the plots.

The size of the plots for spring durum and soft wheat was 14.4x60 m (S is 864m²); for corn, millet and peas it was 3.6x60 m (S is 216 m²). The mass of organic residues (stubble-root residues) was estimated according to the frame recess method described by N.Z. Stankov.

Scheme of the experience:

I. Arable crop rotation with winter rye (black steam - winter rye - spring durum wheat - corn for silage - spring soft wheat - barley);

II. Crop rotation with weed-free fallow for the durum wheat (weed-free fallow - spring durum wheat - spring soft wheat - peas - spring soft wheat - barley);

III. Crop rotation with the fallow (grain fallow cropped by summer sowing of Sudanese grass - spring durum wheat - spring soft wheat - millet - spring soft wheat - barley);

In the experiment, the following variants of field crops were sown: winter rye Saratovskaya 6 with a seeding rate (SR) equals to 4 million viable seeds per hectare, spring durum wheat Orenburgskaya 21 with SR equals to 4.0 million, spring soft wheat Saratovskaya 42 with SR equals to 4.5 Arable crop rotation Anna barley with SR equals to 3.8 mln., Chishminsky peas 210 with SR equals to 1.3 mln., corn for silage ROSS 144 MV with SR equals to 80 thousand, Orenburgskoe millet 20 with SR equals to 1.2 mln.

Agrotechnology of soil cultivation is adopted for the zone of the Orenburg region.

3. Research results

An important function of crop rotation is to regulate the regime of organic matter in the soil through the selection of crops that leave a large volume of stubble-root residues (SRR), replacement of weed-free fallows with occupied ones with an appropriate fertilization system. We have considered three crop rotations with weed-free and cropped fallows.

On average, the largest volume of organic matter was formed in the form of straw and SRR in the crop rotation with weed-free fallows over 10 years (from 2011 till 2020). The mass of winter rye straw that entered the soil averaged 5.92 tons per hectare over 10 years (table 1), and the total volume of organic matter was 11.87 tons per hectare.
Table 1. The input of organic matter in various crop rotations on average for 2011-2020.

| Crop rotation number | Composition and rotation of crops | Organic matter |  
|----------------------|----------------------------------|----------------|
|                      |                                  | stubble root residues straw total |
| weed-free fallow - winter rye | 2.51 3.44 5.92 11.87 |
| spring durum wheat   | 0.70 1.30 1.22 3.22 |
| 1 silage corn        | 0.95 0.51 - 1.46 |
| spring soft wheat    | 0.66 1.64 1.53 3.83 |
| weed-free fallow - spring durum wheat | 0.56 1.23 1.12 2.91 |
| spring soft wheat    | 0.44 1.39 1.17 3.00 |
| 2 pea                | 0.64 2.50 2.47 5.61 |
| spring soft wheat    | 0.52 1.71 1.32 3.55 |
| barley               | 0.61 1.66 1.39 3.66 |
| 3 soil-protective fallow (cropped by Sudanese grass of the summer sowing period) | 0.90 1.83 - 2.73 |
| spring durum wheat   | 0.80 1.65 1.40 3.85 |
| spring soft wheat    | 0.61 1.72 1.34 3.67 |
| millet               | 1.56 2.63 1.82 6.01 |
| spring soft wheat    | 0.70 1.66 1.45 3.81 |
| barley               | 0.69 1.88 1.50 4.07 |

The leafy mass was removed from the field and a small volume of SRR (1.46 tons per 1 ha) entered the soil at the first crop rotation to cultivate the silage corn.

On average of 24.38 tons per hectare of organic matter was received over the years of the experiment in the crop rotation with winter rye. In the grain-fallow crop rotation with peas, 18.73 tons per hectare of stubble-root plant residues (60.1%) were supplied to the soil. In the crop rotation with grain fallow, the volume of organic matter increases due to the SRR of the steaming crop and, on average, 24.14 tons per hectare of organic matter of plant residues are accumulated over 10 years.

On average, over 10 years, the total number of received SRR was 5.57 tons in the first crop rotation, 2.77 tons in the second, and 5.26 tons per hectare in the third (table 2).

Table 2. Productivity of crop rotation, humus content and application of organic residues on average for 2011-2020.

| Crop rotation type                  | Plant residues, tons per hectare | SRR | Crop rotation productivity, 1 t from 1 ha of feed units system | Humus content in a layer of 0-20 cm, % |
|-------------------------------------|----------------------------------|-----|---------------------------------------------------------------|--------------------------------------|
| Arable crop fallow with winter rye  | 5.57 8.72 10.09 7.36 5.12       |     |                                                               |                                      |
| Weed-free fallow with durum wheat   | 2.77 8.49 7.47 5.34 5.08       |     |                                                               |                                      |
| Weed-free fallow                    | 5.26 11.37 7.51 7.22 5.15       |     |                                                               |                                      |
Plant residues entering the soil increase the productivity of crop rotations up to 7.36 tons per hectare of feed units system (in grain-cultivated crops with winter rye). The humus content in the soil depends on the type of the studied crop rotation (in the arable crop rotation, the highest % of humus in the soil is 5.15%, which exceeds by 0.17% the grain-fallow with weed-feed fallow).

The volume of organic residues that entered the soil is influenced by both different crop rotations and their separate links. The largest amount (15.09 tons per 1 ha) of organic matter enters the soil in the weed-free fallow with winter rye (table 3).

Table 3. Volume of organic residues formed by field crops of the crop rotation link (on average for 2011-2020).

| Variant | Fellows and crops of the crop rotation link | Volume of organic substances, t per 1 ha plant residues |  |
|---------|------------------------------------------|-------------------------------------------------------|---|
| Arable crop fallow with winter rye | weed-free fallow, winter rye, spring durum wheat, silage corn, spring soft wheat, barley | 3.21 | 4.74 | 7.14 | 15.09 |
| Grain fallow with weed-feed for durum wheat | weed-free fallow, spring durum and soft wheat, pea, spring soft wheat, barley | 1.00 | 2.62 | 2.29 | 5.91 |
| Weed-free fallow | grain fallow (Sudanese grass), spring durum and soft wheat, millet, spring soft wheat, barley | 2.31 | 5.20 | 2.74 | 10.25 |

The crop link with millet in the grain crop rotation leaves 13.89 tons per 1 hectare of plant residues. In the link of grain-fallow crop rotation with grain fallow, on average of 10.25 tons per hectare of organic matter of plants entered the soil over five years. In this link, the entering of root and stubble mass into the soil increases due to the cultivation of Sudanese grass in a grain fallow.

4. Conclusion

The crop rotation regulates the regime of organic matter in the soil through the selection of crops that leave a large volume of SRR and straw. In our experiment, the largest volume of organic plant residues entered the soil during the cultivation of winter rye in a crop rotation with weed-free fallow and averaged 11.87 tons per hectare over 10 years.

In the grain crop rotation, due to the large organic plant mass of field crops and fallow crops, the humus content in the soil increases by 0.17% compared to grain-fallow with weed-free fallow.

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