Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Technological methods stabilizing humus content of sod-podzolic light loamy soil

O.A. Savoskina[1], I.A. Zavertkin[1], A.I. Kuracheva[2], L.I. Ilyin[2]

1. FSBEI HE RSAU-Moscow Agricultural Academy named after K.A. Timiryazev, Moscow, Russia
2. Department of Economics, Director of FSFRI, Verkhnevolzhsky FASC, Moscow, Russia

ABSTRACT

Intensive use of arable land with unbalanced application of mineral fertilizers negatively affects soil fertility and the environment. Anthropogenic activity alters the relatively stable natural balance. The nature and direction of such alterations are largely determined by the intensity of agricultural practices implemented during field crop growing, among which the most important are the cultivation method, the fertilizer system and chemical soil reclamation. To improve the balance of organic matter in sod-podzolic light loamy soil, it is recommended to apply organic mineral fertilizers with a chemical ameliorant (lime), which reduces the rate of humus mineralization in soil and improves plant nutrition. The article shows the influence of mineral fertilizers, manure and lime on humus balance and its stabilization in the agroecosystem of the long-term field experiment.

Keywords: Soil fertility, Organic matter, Plant residues, Fertilizers, Mineral, Liming, Water resistance, Soil density, Field crops.
Article type: Research Article.

INTRODUCTION

Sustainable agricultural production solves a number of important issues related to the employment of various energy sources, using efficiency of various types of fertilizers and ameliorants, and the impact on the environment, which together contribute to the crop yield elevation, while maintaining and even expanding soil fertility (Yasnolob *et al.* 2019; Shitikova *et al.* 2020; Suanda *et al.* 2023). Soil organic matter plays an important and multifaceted role in the creation and preservation of soil fertility. The nutritional regime of plants and various soil properties (physical-chemical, physical-mechanical, biological and biochemical) are closely related to its content and qualitative composition, which is explained by the peculiarities of the chemical structure, bioavailability, high energy intensity and organic matter activity (Tyurin 1965; Spain *et al.* 1983; Körschens *et al.* 1998; Wander 2004; Mandal *et al.* 2007; Ivanov *et al.* 2017). In modern conditions of agricultural production, the problem of accumulation and preservation of organic matter in sod-podzolic soils remains relevant, since obtaining high yields of field crops with high-quality products at the lowest labor costs and irreplaceable energy is possible only with the optimal levels of soil humus for specific conditions of agricultural landscapes (Kosolapova *et al.* 2016; Mazirov *et al.* 2018). Agricultural crops, which leave different amounts of plant residues for the formation of soil organic matter, are of great importance in the reproduction of soil humus in particular and fertility in general (Magdoff & Weil 2004). A decisive role in the soil humus reproduction increase is played by organic fertilizers, the application rates of which depend on the accumulation of cattle manure or poultry droppings in the farm, determined by the structure of sown areas and the types of crop rotations, the presence of peat and sapropel on the territory of agricultural enterprises or other alternative fertilizers, for example, biochar or biocoal (Granstedt & Kjellenberg 1997). Mineral fertilizers and lime play a stabilizing role in humus formation (Haynes & Naidu 1998; Matyuk & Shevchenko 2017). So, the purpose of our research was to establish the content of organic matter in permanent field crops, pure fallow and crop rotation in time with different use of agriculture intensification factors in a long field experiment.

MATERIALS AND METHODS

This study was carried out in the Long-term field experiment of the FSBEI HE RSAU-Moscow Agricultural Academy named after K.A. Timiryazev, which was founded in 1912 by the Professor A.G. Doyarenko on the initiative of the Academician D.A. Pryanishnikov, located within 55°50′25″ NL and 37°33′29″ EL. The experience was three-factor one (Fig. 1).

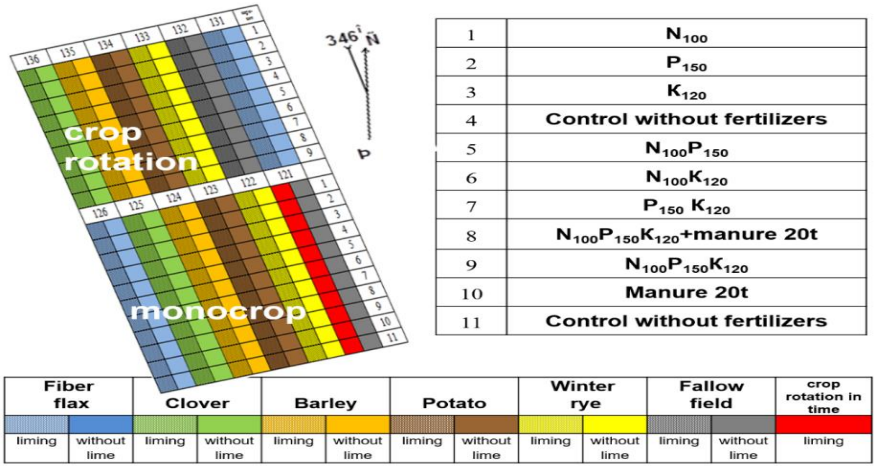

Fig. 1. Schematic plan of the Long-term experience at RSAU-Moscow Agricultural Academy named after K.A. Timiryazev. The source*:* Savoskina *et al.* (2020).

Fiber flax, clover, barley, potatoes, winter rye were grown on the experimental field, and there was a field of pure fallow. A crop rotation was deployed on one half of the plot (the fields 131-136), and permanent cultivation of crops was carried out on the other half (the fields 122-126). In addition, a crop rotation is deployed in time on the field 121 (against a limed background since 1973) and clean fallow (against the background without lime). Since 1949 lime has been introduced 1 time in the crop rotation during the long-term experiment in the doses calculated by the hydrolytic acidity. Nitrogen in the experiment was introduced in the form of ammonium nitrate, phosphorus - double granular superphosphate, potassium - potassium chloride. Cattle manure was used as organic fertilizer.

The main soil cultivation included disking with heavy disc harrows to the depth of 10-12 cm, the introduction of phosphorus, potash and organic fertilizers (according to the options) and plowing with a skimmer plow to the depth of 20-22 cm. The object of this study was the sod-podzolic light loamy soil of the experimental plot, sampled from the depth of the arable layer (0-20 cm) after harvesting field crops. Scientific observations and analyzes were carried out in permanent crops, in a field of pure fallow and during crop rotation in time (the fields 121-126).

The counts were carried out in 2013-2019 on the following options:

- Control (without fertilizers);
- Control on a limed background;
- Manure
- Manure on a limed background (manure + Ca);
- Complete mineral fertilizer (NPK);
- Complete mineral fertilizer on a limed background (NPK + Ca);
- Combined application of full mineral fertilizer and manure (NPK + manure);
- Combined application of full mineral fertilizer and manure on a limed background (NPK + manure + Ca)

The determination of organic matter content was carried out according to the Tyurin method in the modification of CINAO (GOST 26213-91), based on the oxidation of soil organic matter with chromic acid to the formation of carbon dioxide.

RESULTS AND DISCUSSION

Two mutually-opposite processes (synthesis and decomposition) characterize quantitative and qualitative alterations in organic matter. Under natural conditions, these operations are in equilibrium, and each soil is characterized by a certain level of organic matter inherent in it, which persists for a rather long time (Dospekhov 1955). There is an imbalance between the processes of organic matter entering the soil and its losses in the agroecosystems, under the influence of various factors. The plant plays a decisive role in the dynamics of soil

organic matter, since their remains are the main resource for the reproduction of soil fertility in natural cenoses. This role of plant residues decreases in agroecosystems due to the mass of their root system decrease and harvesting loss. Before laying the experiment, the humus content in the soil of the selected area was 2.06%. Subsequently, it decreased at various rates for over 100 years, depending on the method of crop cultivation, fertilization system and chemical reclamation (Table 1).

Table 1. The content of humus in the arable layer of sod-podzolic light loamy soil within permanent crops, pure fallow and crop rotation in time (%)

Crops / Chemical reclamation	**Control without fertilizers**		**$N_{100}P_{150}K_{120}$**		**Manure 20 ton**		**$N_{100}P_{150}K_{120}$ +manure 20 ton**	
	liming	**without lime**	**liming**	**without lime**	**liming**	**without lime**	**liming**	**without lime**
Fiber flax	1.77	1.82	2.23	1.93	2.93	2.57	2.61	2.34
Clover	2.04	2.02	2.17	2.12	2.84	2.64	2.44	2.32
Barley	2.10	1.87	2.27	2.24	2.88	3.08	3.21	3.14
Potato	1.82	1.77	1.94	1.92	2.14	2.12	2.10	2.01
Winter rye	1.65	1.94	2.10	2.37	2.74	3.02	2.97	3.06
Crop rotation in time	1.32		1.64		1.91		1.85	
Fallow field		0.95		1.18		1.82		1.65
Average value	1.78	1.73	2.06	1.96	2.57	2.54	2.53	2.42
Standard deviation	0.28	0.39	0.24	0.42	0.44	0.50	0.51	0.58

According to our data, the fallowing of sod-podzolic light loamy soil for over 100 years without intensification of agriculture caused a sharp decrease in its humus content to 0.95%, which is 46.1% of the original. The stabilizing effect was exerted by the introduction of organic fertilizers (manure 20 ton ha^{-1}), where the humus content was 1.82%, which is 11.7% lower than it was before the laid experiment. Using an organic-mineral fertilizer system restrained the rate of humus loss and stabilized it at the level of 1.65%. Since the long-term fallowing of the soil takes place on an unbroken background, the introduction of a full mineral fertilizer $N_{100}P_{150}K_{120}$ was ineffective in reproducing soil fertility due to a physiologically acid reaction and the humus content in this option was 1.18%. Under permanent crops on an un-limed background, the total carbon content was significantly higher in comparison with fallow - by 39.7% on average for the studied variants. The highest humus content was recorded in the clover field and made 2.02%, indicating mineralization rate decline of organic matter. In the cultivation of grain crops, the humus content of the arable soil layer was 1.94% under winter rye and 1.87% under barley. Winter rye is slightly inferior to perennial grasses in terms of soil humus content. These differences are within the definition error. Consequently, clover and grain crops ensure the maintenance of the soil humus balance and its stabilization in the range of 1.87-2.02 % C, indicating a large soil-protective and ecological role of these crops in the soil humus preservation. The cultivation of a technical culture of fiber flax on an un-limed background led to the humus content reduction (up to 1.82%) due to the alienation of plant residues from the field. A row crop (potatoes) contributed to the intensification of the dehumification process due to the cultivation technology (due to multiple inter-row treatments) and we observed the humus content reduction to 1.77%. As observed, the cultivation of various crops was not able to prevent the content of organic matter reduction in the soil during its long-term agricultural use. Using various systems of fertilizers (mineral, organic-mineral, organic) increased the humus content of the arable layer of sod-podzolic light loamy soil. So, by the option of manure application, there was the humus content elevation relative to the initial one under all cultivated crops: from 2.9% under potatoes to 49.5% when cultivating barley with additional sowing of clover. The maximum values for the humus content noted during the cultivation of barley were associated with low crop yields and, thus, by a slight alienation of organic matter. Using an organic-mineral fertilizer system was slightly inferior to the organic one, however, there was no drop in soil fertility level by the prolonged intensive use. The introduction of mineral fertilizers maintained a deficit-free balance of organic matter after over 100 years of permanent crop cultivation. The humus content has stabilized at 1.32% in the soil of the crop rotation, which is due, on the one hand, to the presence of complete fallow and potatoes, characterized by high mineralization of organic matter, and to clover and grain crops, on the other hand, which restrain the rate of humus decline, conditioned by the supply of fresh organic matter in the soil in the form of root exudates, as well as by the microorganism activity upraise. Thus, the change in the structure of the sown area of the crop rotation will allow to regulate the levels of humus stabilization in soil and thereby provide various approaches to the reproduction of organic matter. Liming of soil made an insignificant effect on the preservation of the soil humus content. Field crops and fallow, according to the effect of their influence on the

soil humus balance, were arranged in the following descending order: clover - winter rye - barley - potato - fallow.

CONCLUSION

After the studies carried out in the Long-term field experiment, they set ecologically justified levels of the humus balance of sod-podzolic soils and technological methods for its stabilization. In a permanent fallow without using fertilizers, the humus content stabilized at 0.95% due to natural processes, while its initial content was 2.06%. Permanent crops of continuous sowing (winter rye, barley, clover and fiber flax) without using fertilizers were able to maintain the humus balance at about 1.90% (potatoes at 1.82%). A stable humus balance was formed at the level of 1.32% in crop rotation (pure fallow - winter rye - potatoes - barley with clover sowing - clover - flax) without application of fertilizers, mainly due to the plant residues entering the soil. Utilizing organic fertilizer and its combined application with a complete mineral fertilizer provides an extended reproduction of organic matter. Liming did not affect the level of the soil humus balance under permanent crops and in crop rotation. The forecast of humus balance level increase or decrease is possible with these technological methods when the structure of the sown area of the crop rotation alteration, taking into account the influence of crops and fallow on the organic matter content.

REFERENCES

Zandbasiri, M, Soosani, J & Pourhashemi, M 2017, Evaluation of the crisis severity in forests of Kohgiluye and Boyerahmad province (Case study: Tang-e Solak). *Iranian Journal of Forest and Poplar Research*, 24: 665-674, [In Persian].

Zarenistanak, M, Dhorde, AG & Kripalani, RH 2014, Trend Analysis and Change Point Detection of Annual and Seasonal Precipitation and Temperature Series over Southwest Iran. *Journal of Earth System Science*, 123: 281-295. Granstedt, A & Kjellenberg, L 1997, Long-term field experiment in Sweden: Effects of organic and inorganic fertilizers on soil fertility and crop quality. In: Proceeding of an International Conference in Boston, Tufts University of Agriculture. Production and Nutrition, 1-11 Massachusetts.

Haynes, RJ & Naidu, R 1998, Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: A review. Nutrient Cycling in Agroecosystems, 51: 123-137.

Ivanov, AL, Kogut, BM, Semenov, VM, Tyurina Oberlander MI & Waxman Shanbacher, N 2017, Development of the theory of humus and soil organic matter: From Tyurin and Waxman to the present day. Bulletin of Soil Institute named after V.V. Dokuchaev, 90: 3-38, DOI: 10.19047/0136-1694-2017-3-38.

Körschens M, Weigel A & Schulz E 1998, Turnover of soil organic matter (SOM) and long-term balances – tools for evaluating sustainable productivity of soils. Zeitschrift für Pflanzenernährung und Bodenkunde, 161: 409-424.

Kosolapova, A, Yamaltdinova, V, Mitrofanova, E, Fomin, D & Teterlev, I 2016, Yields of field crops and sod-podzolic soil fertility of west Ural depending on fertilizer system. Bulgarian Journal of Agricultural Science, 22: 381-385.

Magdoff, F & Weil, RR 2004, Soil organic matter management strategies. In: Soil organic matter in sustainable agriculture. F, Magdoff, RR, Weil, Boca Raton et al. (Eds.): CRC Press, pp. 45-65.

Mandal, A, Patra, AK, Singh, D, Swarup, A, Masto, RE 2007, Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. Bioresearch Technology, 98: 3585-3592.

Mazirov, MA, Matyuk NS, Polin VD, Malakhov NV 2018, Influence of different systems of processing and fertilization on the fertility of sod-podzolic soil. *Agriculture,* 2: 33-36.

Matyuk, NS, Shevchenko VA The effect of various fertilization systems and the methods of sod-podzolic soil processing on the content of humus, nutrients and the yield of crops in crop rotation. Fertility. 2017. No. 1(94). pp. 26-29.

Savoskina, OA, Shitikova, AV & Chebanenko, SI 2020, Change of the content of soil water stable aggregates in a fallow field depending on the cultivation level of albic glossic retisols of long-term field experience. International Journal on Emerging Technologies, 11: 475-478.

Shitikova, AV, Bazhenova SS, Lyakina VO 2020, Prospects for the development of crop product organic production. From the collection "Plant growing and meadow growing." The collection of the articles of All-Russian scientific conference with international participation. pp. 804-808.

Spain, AV, Isbell, RF & Probert, ME 1983, Soil organic matter. In: 'Soils: an Australian viewpoint', Division of Soils, CSIRO, pp. 551-563 (CSIRO: Melbourne/Academic Press: London).

Suanda, IW, Martanto, EA, Iriani, F, Nurhayati, Farni, Y, Wirda, Z & Sutiharni, S 2023, Integrated pest control strategy (IPM) corncob borer (*Helicoverpa armigera* Hubner): Fertilization and weeding control. *Caspian Journal of Environmental Sciences*, 21: 395-402

Tyurin, IV 1965, Soil organic matter and its role in fertility. Publishing House Nauka, 322 p.

Wander, M 2004, Soil organic matter fractions and their relevance to soil function, soil organic matter in sustainable agriculture. In: F, Magdoff, RR, Weil, Boca Raton et al. (Eds.), CRC Press, pp. 67-102.

Yasnolob, IO, Chayka, TO, Gorb, OO, Galych, OA, Kalashnyk, OV, Konchakovskiy, YeO, Moroz, SE & Shvedenko, PYu 2019, Using resource and energy-saving technologies in agricultural production as a direction of raising energy efficiency of rural territories