Field crop rotations in organic agriculture of the Volgograd region

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Abstract. Soil fertility in biologized crop rotations depends on the saturation of them with legumes and sideral crops, perennial grasses, the involvement of grain crops in the organic matter cycle. The crop rotation was studied: 1) four-field grain and steam: clean steam - winter wheat - chickpeas - spring barley (control); 2) five-field grain and steam: occupied steam (clover green manure) - winter wheat - chickpeas - spring barley - mustard + clover; 3) seven-field grain and grass: occupied steam (green manure oats) - winter wheat - mustard - chickpeas - safflower dyeing - spring barley - sainfoin (hatcher field); 4) semi-field grass and grassland: occupied steam (phacelia green manure) - winter wheat - spring wheat - chickpeas - grain sorghum - spring barley - alfalfa (hatchery field). The highest balance of organic matter was ensured in a five-field grain-steam crop rotation with clover for green manure +1.92 t/ha, in this crop rotation the highest balance was observed for nitrogen - +23.8 kg/ha and phosphorus - +1.3 kg/ha, grain harvest from 1 ha of arable land - 0.51 t/ha. The greatest balance of potassium was ensured in the seven-field grain and grass-crop rotation with facet on green manure - +8.8 kg/ha. The highest humus balance was observed in a seven-field grain-grass-crop rotation with oats per green manure - +0.12 t/ha.

1 Introduction

As a result of the application of intensive crop cultivation technologies, the anthropogenic impact on the soil and its degradation increased, the environmental situation in the production of crop production worsened, which led to a decrease in soil fertility and humus reserves [1-5]. To solve these problems, it is necessary to develop specialized field crop rotations that would be the basis for organic farming in the region, which would allow them to adapt as much as possible to natural complexes and obtain stable ecologically clean crop production [6, 7].

The increase in soil fertility in field crop rotations is closely related to their saturation with legumes and sideral crops, perennial grasses, the involvement of non-commodity part of the crop cultivated crops in the organic matter cycle. The selection and assessment of specialized crop rotation for organic farming in the Volgograd region is carried out not only by productivity and production and economic criteria, but also by the amount of labile organic matter, elements of mineral nutrition, and humus reserves.

In crop rotations with alfalfa, sainfoin, and clover fields, organic losses are compensated by humification of the root residues of legumes. This will increase the level of profitability of grain production in the agrocenosis by involving the maximum amount of phytomass formed in the organic matter cycle. Replacing pure steam with employed will reduce the loss of humus in the soil due to mineralization [8-10].

The purpose of the study was to develop specialized field crop rotations for organic farming in the Volgograd region, ensuring reproduction of soil fertility, the largest collection of crop products from 1 ha of crop rotation area based on renewable biological resources.

2 Materials and methods

Studies were carried out in the dry steppe zone of chestnut soils of the Volgograd region in 2018-2019. The object of research is specialized field crop rotation, which was developed for organic farming.

The climate of the subzone is sharply continental. It is characterized by dry autumn and wet spring. Summer is hot and dry. The average annual air temperature is about +10 °C, the average annual rainfall is 339.2 mm. The total precipitation for the years 2017-2018 and 2018-2019 agricultural years, respectively, was 391 and 388.3 mm. The duration of the frost-free period ranges from 180-200 days. Winters are not snowy, warm, and often lower temperatures are down to -35 °C. Longer dry periods are observed annually during the growing season of crops.

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The soil of the experimental plot is light-chestnut silt-coarse-grained, heavy loamy - the content of physical sand is 49.3%, physical clay is 50.7%, humus in the arable 0-0.3 m soil layer is 1.74-2%, total nitrogen is 0.12%, phosphorus - 0.11%. The amount of exchange bases is 25.7 milligram-equivalent/100 g of soil, therefore, has a low metabolic activity. The degree of availability of hydrolyzed nitrogen is low - 3.2-4 mg, average phosphorus mobility - 1.7-3 mg and increased potassium exchange - 30-40 mg/100 g of soil. The reaction of the soil solution is slightly alkaline. In the arable layer, pH-8.1. The salinity of the parent rock and the varying degree of solonetzic soil profile determine the adverse water-physical properties of the soil.

The experiment was conducted in accordance with the generally accepted methodology of field experience according to B. A. Dospekhov. The placement of experience options is randomized. Repeat three times. The total area of the experimental plot is 900 m^2 (18×50 m), the accounting area is 728 m^2.

We studied the following schemes of specialized field crop rotation in organic farming of the Volgograd region:

1) four-field grain and steam: pure steam - winter wheat - chickpeas - spring barley (control), in which pure steam and legumes occupied 25%, grain crops – 50% of the crop rotation area;

2) five-field grain and steam: occupied steam (sweet clover for green manure) - winter wheat - chickpeas - spring barley - mustard + melilot, here occupied steam, legumes and oilseeds occupied 20%, cereals - 40% of arable land;

3) seven-field grain and grass: occupied steam (oats per green manure) - winter wheat - mustard - chickpeas - safflower dyeing - spring barley - sainfoin (hatchery field), where occupied steam, legumes and legumes occupied 14.3%, grain and oilseeds crops – 28.5% of the crop rotation area;

4) semi-field grass and grassland cultivation: occupied steam (phacelia to green manure) - winter wheat - spring wheat - chickpea - grain sorghum - spring barley - alfalfa (hatchery field), in which occupied steam, legumes, row crops and legumes occupied 14.3% and crops – 42.8% of arable land.

In the studied field specialized crop rotation, the generally accepted technology of cultivation of agricultural crops was applied, with the exception of the techniques studied. In the first control crop rotation, the straw of cultivated crops was removed from the field, only the crop-root residues were plowed into the soil. In the second, third, and fourth crop rotations, straw and crop-root residues were embedded in the topsoil with a «Heavy disc harrow-3» to a depth of 0.1-0.12 m. Before disking straw of cereal crops, ammonium nitrate was added per 10 kg of active substance for 1 t. In these crop rotations, instead of pure steam, occupied pairs with clover, oats and phacelia on green manure, which were the precursors of winter wheat, were introduced into the structure of sown areas.

Donnik Koldybansky was sown in a binary way with mustard at a rate of 6 million pcs/ha, Astor oats at a rate of 3.5 million pcs/ha, and Ryazanskaya phacelia at a rate of 4 million pcs/ha in clean sowing in the spring. In June, sweet clover and phacelia in the budding phase, oats in the sweeping phase were crushed with a heavy disc harrow BDT-3 and planted into the soil to a depth of 0.1-0.12 m as a green fertilizer.

In September, after pre-sowing cultivation, Kamyshanka 5 winter wheat was sown with a sowing rate of 3 million pcs/ha with a Don-114 grain seeder to a depth of 0.06-0.08 m. The main tillage consisted of chiseling to a depth of 0.3-0.32 m with a surface layer revolution of 0.2-0.22 m using Chisel-dump gun-5-40 tool with multifunctional working parts of the «RANCHO» modular type (dump and wide chisel). Chickpeas Privo 1 were sown with a seeding rate of 500 thousand pcs/ha, spring barley Medicum 139 - 3.5 million pcs/ha, mustard flagship Sarepta - 1.5 million pcs/ha, safflower Alexandrite - 300 thousand pcs/ha, spring wheat Kamyshinskaya 3 - 3.5 million pcs/ha, sorghum grain Kamyshinskoye 64 - 300 thousand pcs/ha, sainfoin Peschaniy 1251 - 6 million pcs/ha, alfalfa Vega 87 - 5 million pcs/ha.

3 Results and discussion

To characterize specialized field crop rotation, an analysis of possible losses of soil fertility due to alienation of crop residues and grain from crops from the field is necessary. By changing the composition of crops and their alternation in crop rotation, you can control the parameters of organic matter. The highest content of plant debris in the soil is provided by perennial grasses, the lowest - by row crops. Based on this, it is possible to predict the combined effect of crop rotation on the dynamics of organic matter in the soil, the amount of which increases due to the expansion of crops of perennial leguminous grasses, green manure and leguminous crops, occupied steam, the introduction of cultivated crops into the straw soil, while the increase in the specific gravity of row crops, net steams in crop rotation leads to a decrease in the intake of plant residues in the soil [11-13]. These dynamic processes are associated with the balance of organic matter in the soil (Table 1).

From the data in Table 1, it can be seen that on average over two years less green manure was alienated in crop rotations, but more organic matter entered the soil: in five- and seven-field crop rotations, respectively, 2.42; 2.21 and 1.95 t/ha. In these crop rotations, a positive balance of organic matter was ensured. The highest value was noted in a five-field grain-crop rotation with clover for green manure +1.92 t/ha, the lowest - in a seven-field grain-grass-grass crop rotation with phacelia on green manure +1.5 t/ha. In the control variant, where the straw of cultivated crops was removed from the field, a negative balance of organic matter of -0.55 t/ha was ensured.

Table 1. Balance of organic matter in field crop rotations, t/ha of crop area (average for 2018-2019)

Option No.	Crop rotation	Reception of biological function	Accumulated	Aloof	Entered the soil	Balance, ±
1 (control)	Grain-steam four-field	Crop and root residues	2.11	1.33	0.78	-0.55
2	Grain-steaming sideral five-field	Stubble-root remains, melilot green manure, straw	2.92	0.5	2.42	+1.92
3	Grain steam herbal sideral seven-field	Stubble-root remains, oats, green manure, straw, lead a field of sainfoin	2.71	0.5	2.21	+1.71
4	Grain steam grass row sideral seven-field	Stubble-root remains, phacelia green manure, straw, lead a field of alfalfa	2.4	0.45	1.95	+1.5

Many years of research by scientists have established that crop rotation, even under conditions of specialization and intensification, remains a key link in modern farming systems that ensure the efficient use of organic fertilizers [14]. The use of green manure, the incorporation of crop-root residues, the application of mineral fertilizers in the grain-crop rotation are effective components of the organomineral fertilizer system, which provides a nutrition-free balance of nutrients [15]. A positive balance of the main nutrients in the soil was ensured only in a four-field grain-cultivated green manure rotation, where, in addition to straw and leaf-stem mass of cultivated crops, an additional organic substance in the form of winter rye green manure also entered the arable soil layer: nitrogen +39.7; phosphorus +0.7 and potassium +49.9 kg/ha [16]. Regulation of the nutritional regime of soils, expanded reproduction of soil fertility is achieved by applying organic fertilizers in the form of crop-root residues and straw of grain crops, green manure, sowing perennial grasses (Table 2).

Table 2. Dynamics of the main nutrients with organic matter of field crops in specialized crop rotation, kg / ha of crop rotation area (average for 2018-2019)

Option No.	Accumulated			Aloof			Entered the soil			Received with an allowance for ammonium nitrate			Balance, ±		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1 (control)	24.7	5.5	6.9	18	4	4.3	6.7	1.5	2.6	6.7	1.5	2.6	-11.3	-2.5	-1.7
2	35.8	7.9	10.5	13.6	3.3	1.3	22.2	4.6	9.2	37.4	4.6	9.2	+23.8	+1.3	+7.9
3	31.7	7.3	9.7	12.2	3.1	2.2	19.5	4.2	7.5	34.6	4.2	7.5	+22.4	+1.1	+5.3
4	29.3	6.8	12.8	10.5	2.9	2	18.8	3.9	10.8	30.9	3.9	10.8	+20.4	+1	+8.8

From the data in Table 2, it can be seen that, on average, over the two years of research, the highest amount of nitrogen and phosphorus per 1 ha of crop rotation accumulated in a five-field grain-crop rotation with clover on green manure, respectively 35.8 and 7.9 kg/ha, and potassium in a seven-field grain-crop crop rotation with phacelia on green manure - 12.8 kg/ha. Alienated with the organic matter of cereals in sideral crop rotations, the nutrient element was less than in the control.

A positive balance of batteries was ensured in all sideral crop rotations. So, it was the highest in nitrogen and phosphorus in a five-field grain-crop rotation with a clover for green manure, respectively +23.8 and +1.3 kg/ha. The potassium balance in this embodiment was +7.9 kg/ha. In the seven-field grain and grass-crop rotation with phacelia on green manure, the lowest positive balance of nitrogen and phosphorus was provided +20.4 and +1 kg/ha, respectively, but the highest potassium balance was +8.8 kg/ha. The balance of the main nutrients in a seven-field grain-grass and crop rotation with oats for green manure on nitrogen was +22.4 kg/ha, phosphorus - +1.1 kg/ha, potassium - +5.3 kg/ha. In the control variant, where the straw of grain crops was alienated from the field, the balance of the main nutrients was negative.

Scientists have found that humus in the soil is not only a source of nutrients, but also a source of energy for soil microflora, which determines the processes of mineralization of organic matter entering the soil. The systematic use of organic fertilizers (manure), green manure, straw, together with crop-root residues contributed to the supply of dry biomass to the soil on average per 1 ha of crop rotation in the range from 5.75 to 6.18 t. This amount is enough to achieve a humus-free balance.

For a steady increase in the content of organic matter in the structure of biologized crop rotation, perennial leguminous grasses should occupy at least 30-40%. In crop rotations without perennial grasses, in order to achieve a deficiency-free humus balance, it is necessary to have sideral steam and use straw as fertilizer at least

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two times per rotation [17, 18]. The increase in the intake of organic matter in the soil contributed to the intensification of the processes of humification in the soil and the accumulation of humus in it (Table 3).

From the data in Table 3, it can be seen that on average for two years the lowest salinity of humus was provided in seven-field green manure rotation with oats and phacelia on green manure - 0.13-0.14 t/ha, which is 0.22-0.23 t/ha lower than the control. In a five-field green manure crop rotation with a clover on green manure, humus losses were 0.17 t/ha, which is 0.19 t/ha lower than the control. In the control, this indicator was the highest and amounted to 0.36 t/ha.

Table 3. Humus balance in field crop rotation, t/ha (average for 2018-2019)

Option No.	Crop rotation	Humus		
		mineralization	humification	balance, ±
1 (control)	Grain-steam four-field	0.36	0.08	-0.28
2	Grain-steaming sideral five-field	0.17	0.26	+0.09
3	Grain steam herbal sideral seven-field	0.14	0.26	+0.12
4	Grain steam grass row sideral seven-field	0.13	0.23	+0.1

The highest humification of organic matter was achieved in a five-field cereal with clover for green manure and seven-field cereal and grass with oats for green manure crop rotation - 0.26 t/ha, which is higher than the control by 0.18 t/ha, where this figure was 0.08 t/ha . In a seven-field grain-steed with grassland with phacelia on the crop rotation, humification was higher than the control by 0.15 t / ha and amounted to 0.23 t/ha.

A positive humus balance was ensured in all sideral crop rotations. It was the highest in a seven-field grain and grass-crop rotation with oats for green manure - +0.12 t/ha, slightly lower in a seven-field grain-grass and grassland with phacelia on green manure +0.1 t/ha and the lowest in a five-field grain-crop rotation with clover for green manure - +0.09 t/ha. In the control, where all plant crop residues were alienated from the field, this indicator was negative and amounted to -0.28 t/ha.

Many years of research by scientists have established that the productivity of crop rotation depends on the composition and alternation of crops, their level of yield. Of all crop rotations, the most productive in terms of grain yield was grain steam, in which peas were cultivated in black rocker pair, the smallest grain yield was observed in grain and crop rotation. The most productive crop rotations for grain yield per 1 ha of arable land were: rocky steam - durum wheat - soft wheat - peas - soft wheat - barley (against a fertilized background of 0.98 t/ha, unfertilized - 0.90 t/ha); green manure steam - durum wheat - soft wheat - peas - soft wheat - barley (against a fertilized background of 0.98 t/ha, unfertilized - 0.82 t/ha) [19-21]. In our studies, grain harvest in specialized field crop rotations depended on the amount of organic matter entering the soil with crop-root residues, the straw of the crops grown in them, and on the green mass of green manure (Table 4).

Table 4. Grain harvest in specialized field crop rotations, t/ha of crop rotation area (average for 2018-2019)

Option No.	Crop rotation	Reception of biological function	Grain harvest		
			2018	2019	average
1 (control)	Grain-steam four-field	Reception of biological function	0.44	0.45	0.44
2	Grain-steaming sideral five-field	Stubble-root remains, clover green manure, straw	0.66	0.36	0.51
3	Grain steam herbal sideral seven-field	Stubble-root remains, oats, green manure, straw, lead a field of sainfoin	0.51	0.32	0.41
4	Grain steam grass row sideral seven-field	Stubble-root remains, phacelia green manure, straw, lead a field of alfalfa	0.46	0.33	0.39
LSD_{05} = 0.05					

From the data in Table 4, it can be seen that in 2018, a higher grain harvest was ensured in field crop rotation than in 2019. On average, over two years of research, the highest grain harvest from 1 ha of crop rotation area was achieved in a five-field green grain crop rotation, where into the soil straw of field crops and the sideral mass of sweet clover were 0.51 t/ha, which is 0.07 t/ha or 15.9% higher than the control.

Grain harvesting is reduced compared to the control variant in seven-field grain and grass with oats for green manure and grain and grass and grass with phacelia for green manure crop rotation, respectively, 0.03 and 0.05 t/ha or 6.8 and 11.4%. In the control, where the straw of cultivated crops was alienated from the field, this indicator was 0.44 t/ha.

4 Conclusion

To increase the productivity of specialized crop rotations and the fertility of light chestnut soils in the dry steppe zone of the Volgograd Region, it is necessary to introduce a five-field field crop rotation with a plowed soil for the clump of clover, crop-root residues and straw of grain crops. The use of this crop rotation ensured a positive balance of organic matter in the soil +1.92 t/ha, nitrogen and phosphorus, respectively, +28.8 and +1.3 kg/ha, humus - +0.09 t/ha, increased grain harvest from 1 ha of arable land by 15.9%.

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