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Productivity of crop rotations with perennial grasses and leguminous crops in the dry-steppe zone of the Lower Volga region

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Abstract

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The research was carried out in the fields of the Lower Volga Research Institute. The work was completed in 2017-2020. The soil of the experimental site is light chestnut, heavy loamy, with a humus content of 1.74% in the arable layer. The average annual precipitation was 339.7 mm. The technology of cultivation of these crops was generally accepted for the research area. The placement of options (A) is sequential and options (B) are placed in blocks in three tiers. The main tillage in the experiment is soil-free, treated with a SibPME stand to a depth of 25-27 cm. Zoned varieties of agricultural crops are cultivated. Records and observations were carried out according to the recommendations. During the period July-August, the largest amount of precipitation fell in 2016 – 119.0 mm; the smallest in 2017 – 6.0 mm, in other years this indicator was in the range of 32.8...86.0 mm. On average, over the years of research, the largest accumulation of crop residues, straw and roots in a 4-pole crop rotation with black steam is 3.4 t/ha. The amount of nitrogen entering the soil with straw and crop residues was noted in an 8-month crop rotation of 49.8 kg/ha. The largest amount of biological nitrogen (according to Trepachev's method) was accumulated under alfalfa crops of 34.4 kg/ha. The analysis of soil samples for the content of humus over the years of research did not reveal significant changes. The best precursor for winter wheat is black steam. For perennial grasses, peas, the grain yield of winter wheat in some years is reduced by 4 ... 12 c/ha. The analysis of the correlation dependence of crop rotation productivity showed that the highest dependence with precipitation for May-June is t = + 0.50 for grain and feed units and slightly less for protein-t = +0.26-0.50.

Keywords: crop rotations; perennial grasses; leguminous crops; dry-steppe zone; Lower Volga region

Introduction

In the Russian Federation, grain production is carried out mainly in arid regions, including the Volgograd region. In terms of grain production, the region is on the 5th place in the Russian Federation (Belenkov, 2010; Denisov, 2009). Currently, it is planned to have up to 2 million hectares for sowing winter crops in the Volgograd region. The development of the grain industry is carried out by mastering the previously developed system of " dry " agriculture. The zonal system is based on highly specialized steam grain crop rotations with a steam area of up to 50%. The percentage share of legume and grass forage crops in mixtures influences the quality and nutritional value of forage. Their ability to combine and the competitiveness are important factors in maintaining dynamic stability in the grassland (Bozhanska, 2017;

Bozhanska & Churkova, 2020). However, solving the grain problem in conditions of extremely limited resource supply, such crop rotations, although they contribute to the stabilization of grain production, at the same time reduce the content of organic matter in the soil, which leads to a deterioration of its fertility, which is one of the main components of crop productivity (Balashov & Agafonov, 2011; Zelenev et al., 2017).

Soil fertility is characterized by three main groups of factors: agrochemical, agrophysical and biological. Science has accumulated a huge amount of material on the optimization of indicators of these soil properties, scientifically based farming systems for various soil and climatic zones have been developed, models of effective soil fertility management have been proposed, as well as ways to make the most complete use of the bioclimatic potential (Alimova, 2009; Zelenev, 2007).

Recently, the focus on fertilizers of agrogenic origin (siderates, straw, crop residues)has been significantly expanded (Smutnev & Volynskov, 2005).

Compared to other types of organic fertilizers, they have advantages: the speed of reproduction, inexhaustibility, relatively low energy and labor costs for their production, environmental cleanliness, phytomeliorative role. Green fertilizers bind nutrients during the growing season, protecting them from leaching and other losses, reduce the content of pathogenic microorganisms and the amount of weed vegetation (Gubareva & Shakhbazova, 2015; Pavlov et al., 1997).

As the main agrobiological tool that ensures the achievement of these goals, a scientifically based crop rotation is adopted as a way to regulate the intake and quality of organic matter into the soil and the speed of its transformation (Zakharov et al., 2009).

In this regard, our research is aimed at developing the optimal structure of arable land and crop rotations for the current situation.

Purpose of the work: On the experimental field of the Lower Volga Research Institute of Agricultural Research, four crop rotations with different saturation of them with perennial grasses and leguminous crops are developed in space and in time. From grasses in the experiment were sown biennial sweet clover, alfalfa, sainfoin and annual sweet clover, from legumes – peas and chickpeas.

Materials and Methods

Crop rotations are placed on a plot with a slope of up to 1° in the north-eastern direction. According to the classification, the working area (contour) belongs to class I, on which it is possible to cultivate all crops. The soils of the experimental site are light chestnut, but the survey results contain 1.7-2.3% humus, soil pH from 7.2 to 7.8, total nitrogen 0.12-0.19%, total phosphorus 0.12-0.15%, total potassium 1.26-2.06%. The arable soil layer contains available phosphorus 90-100 kg, exchangeable potassium 1080-1296 kg, nitrogen (NO_3) – 72-90 kg. The content of heavy metals and pesticides does not exceed the maximum permissible concentration. The main tillage in the experiment is soil-free, treated with a SibPME stand to a depth of 25-27 cm. Zoned varieties of agricultural crops are cultivated. Perennial grasses are sown under cover. The seeding rate of the cover crop is reduced by 30-40% from the one taken when sowing in pure form. After harvesting grasses of one-year use for hay or green fodder, the soil is prepared for sowing winter wheat, which consists in double disking with a heavy disc harrow, and then, as weeds appear, cultivation and sowing of winter wheat is carried out in the recommended time.

Harvesting of grain crops is carried out by a combine harvester with a chopper, followed by embedding the crushed straw into the soil with a heavy disk harrow. Fertilizers and pesticides are not used in the experiment.

Results and Discussion

The study period of 2015-2019, according to moisture and heat supply, is characterized as very arid and dry, the HTC (hydrothermal coefficient) in these years was in the range of 0.1-1.4. The supply of productive moisture at the beginning of the growing season was 33.0-136.7 mm (Table 1).

Table 1. Meteorological conditions for the growth and development of grain crops in the years of research

Years	Solar activity, Wolf's number	Reserve of productive moisture, mm	The amount of precipitation for May and June, mm	Temperature, °C	
				May	June
2015	110.9	136.7	96.5	18.9	25.5
2016	104.1	109.5	107.9	17.7	23.3
2017	63.6	113.7	82.4	16.5	21.4
2018	43.9	136.1	19.9	21.1	24.9
2019	21	127.0	64.3	19.9	26.9

Table 2. The content of total and" biological " nitrogen in the roots of perennial grasses, peas and winter wheat

Variant	Yield of dry weight, c/ha	Nitrogen in the crop		Share of biological nitrogen, kg/ha
		%	kg/ha	
Alfalfa	20.0	2.4	48.0	34.4
Esparcet	19.3	1.7	32.8	19.2
Biennial sweet clover	20.9	1.9	39.7	26.1
Annual sweet clover	15.0	2.0	30.0	16.4
Peas	16.0	1.8 .	29.3	15.7
Winter wheat	16.0	0.93	14.9	–

The amount of precipitation for the period May-June, which are decisive in the formation of the harvest of early grain crops in the years of the study, was not the same. The largest amount fell in 2016 – 107.9 mm; in 2015 -96.5 mm, the smallest amount fell in 2018 and 2019 -19.9 and 64.3 mm. Solar activity (Wolf number) was the lowest in 2019 -2021, the maximum-110.9 in 2015.

During the period July-August, the largest amount of precipitation fell in 2016 – 119.0 mm; the smallest in 2017 – 6.0 mm, in other years this indicator was in the range of 32.8...86.0 mm.

The amount of nitrates in the soil in the spring period was also not the same by year: under winter wheat crops, a couple of 50-220 mg per 1000 g of soil, for perennial grasses-19 mg per 1000 g. Their greatest amount is observed in the wet and warm months of spring – April, May and the least in the drier and colder ones. Under the crops of spring crops, the nitrate content in different years was in the range of 8.7... 17.3 mg/1000 g of soil.

On average, over the years of research, the greatest accumulation of crop residues, scrap and roots in a 4-pole crop rotation with black steam was 3.4 t/ha, in two 5-pole crop rotations with perennial sweet clover and alfalfa 3.2...3.1 t/ha and in an 8 – pole crop rotation with leguminous crops – 3.2 t/ha. For other crop rotations, this indicator is lower. The amount of nitrogen entering the soil with straw, crop residues in the fields of crop rotation is not the same. A greater number was observed in the 8-pole crop rotation of 49.8 kg/ha; in the 4-pole-38.1 kg/ha and 5-pole crop rotations with perennial grasses of 35.2-37.1 kg/ha (Table 2).

The proportion of biological nitrogen in the crops of grasses and peas was determined according to the Trepachev method. The largest amount of it accumulated under alfalfa crops of 34.4 kg/ha and perennial sweet clover-26.1 kg/ha, under esparcet, annual sweet clover and go-roh, its amount was 19.2; 16.4; 15.7 kg/ha, respectively (Figure 1).

Before starting the experiment in 2015, an analysis of soil samples for humus content was carried out, which showed that the experimental site is not homogeneous in terms of humus content. The intra-field humus content ranges from

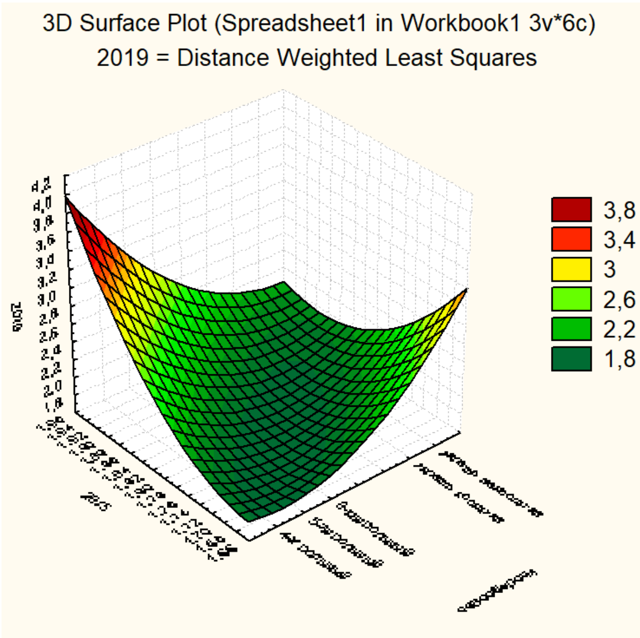

Fig. 1. Changes in the humus content during the years of research on various crop rotations

1.68 to 23.3% of humus. The analysis of soil samples taken in 2019 for the content of humus shows that its amount is almost at the level of 2015 indicators. The material was processed in the Statistika program, data were obtained.

The figure shows that the studied crop rotations with a different set of agricultural crops did not have significant changes in the humus content – 1.77-1.79%. Even on fallow lands over these years, the humus content was in the range of 1.80-1.83% (Figure 2).

The meaning of these graphs is simple: the points in the center of the rectangles correspond to the average values of the variables of 2015 and 2019. The average was taken by cases: the humus indicators for crop rotations were summed up and divided by the number of cases, i.e. by the number of crop rotations. From these values, a positive standard deviation, a negative standard deviation, a positive standard

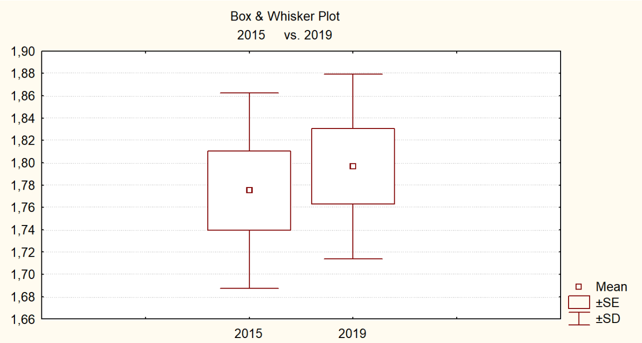

Fig. 2. The "box with whiskers" graph for humus variables of 2015, 2019

error, a negative standard error were taken, "whiskers" and "boxes" were obtained (Table3).

The results table shows sequentially: the average values of humus indicators for 2015 and 2019, standard deviations, the number of observations, the difference between the average values of variables in 2015 and 2019, the value of the t – criterion statistics, the number of degrees of freedom, the level of significance. Note that the values in the table are not highlighted in red, this shows that the difference in the average values of humus indicators in 2015 and 2019 is not significant (Table 4).

The yield of agricultural crops in the years of research, first of all, depended on the moisture supply, and then on the predecessors. The best precursor for winter wheat is black steam. For perennial grasses, peas, the grain yield of winter wheat in some years is reduced by 4 ... 12 c/ha. On average, for 5 years of research, the winter wheat grain yield for black steams was 2.3 t/ha.

The precursors of esparcet and peas reduced the productivity of winter wheat by 0.2-0.3 t/ha. Meteorological conditions for the growth and development of grain crops had a much greater impact on the productivity of crops (Table 5).

There is a close dependence of winter wheat productivity on the supply of productive moisture (t = + 0.60) and precipitation for May and June t = +0.50-0.70.

There is a weak correlation between the yield and the solar activity of the average daily temperature for May and even a negative dependence on the average daily air temperature for June. The closest relationship between the yield of spring cereals and peas with precipitation for May and June is t = + 0.50-+0.62.

Table 3. Spreadsheet of results

Variable	T-test for Dependent Samples (Spreadsheet1 in Workbook1) Marked differences are significant at p < ,05000							
	Mean	Std. Dv.	N	Diff.	Std. Dv. Diff.	t	df	P
2015	1.775000	0.087350						
2019	1.796667	0.082624	6	-0.021667	0.042622	-1.24517	5	0.268241

Table 4. Productivity of the main grain crops in crop rotations

Years	Yield, t/ha					
	Winter wheat by predecessors			Spring wheat	Barley	Peas
	Black steam	Esparcet	Peas			
2015	2.6	2.5	2.5	1.4	1.6	1.5
2016	3.1	1.9	2.8	0.7	0.8	0.23
2017	1.8	1.5	1.5	2.09	2.5	2.1
2018	2.5	2.3	2.2	1.29	1.4	1.02
2019	2.8	2.1	1.9	0.5	0.6	1,1
Average	2.3	2.0	2,0	1.1	1.7	1.4

Table 5. Correlation dependence of grain yield on the solar activity of productive moisture, precipitation and the average daily temperature in May and June

Agro-climatic factors	Winter wheat by			Yield of agricultural crops		
	Black steam	Esparcet	Peas	Spring wheat	Barley	Peas
Solar activity, Wolf number	-0.13	-0.14	0.04	0.02	-0.16	-0.05
Precipitation, mm	0.51	0.70	0.50	0.50	0.58	0.62
Productive moisture	0.60	0.49	0.36	0.01	0.39	0.21
Average daily temperature in May, t°C	0.15	0.17	0.03	0.13	0.20	0.12
Average daily temperature in June, t°C	-0.62	-0.62	-0.50	-0.52	-0.56	-0.47

An increase in the average daily air temperature from the optimal one leads to a negative dependence – t = + 0.47-0.52.

The largest grain yield from 1 ha of the crop rotation area for an average of 5 years was 1.2 t/ha in a 4-field crop rotation and 1.4 t/ha in an eight – field crop with leguminous crops.

The maximum yield of grain from 1 ha of the crop rotation area was in 2016 in the eight-field -2.9 t/ha and the minimum-0.1 t/ha in the four-field with black steam and five-field with sweet clover and esparcet.

The total yield of crop production in feed units in the crop rotation with two-year-old sweet clover and grain sorghum was 2.8 t/ha and in the crop rotation with black steam 2.5 t. According to the protein yield from 1 ha of the crop rotation area, the studied crop rotations provided equivalent indicators – 0.3 t/ha, and the crop rotation with black steam was 100 kg/ha less.

The analysis of the correlation dependence of crop rotation productivity showed that the highest dependence with precipitation for May – June is t = + 0.50 for grain and feed units and slightly less for protein-t = +0.26-0.50.

Conclusions

For each millimeter of moisture, the largest amount of grain was obtained in the crop rotation with leguminous crops – 6.4 kg and four-field with black steam – 4.3 kg, and energy costs per 1 kg of grain are higher in crop rotations with perennial grasses, per feed unit in almost all crop rotations, except for the crop rotation with black steam.

The determination of the gross energy for each crop and per unit area of crop rotation, as well as the total energy costs and bioenergetic potential showed that in an eight-field crop rotation with leguminous crops, energy production was 21.5 GJ/ha, which is higher than in a 4-field crop rotation by 10.4 GJ/ha. Thus, with a shortage of mineral fertilizers and plant protection products, the introduction of perennial grasses of one-year use, as well as leguminous crops, into crop rotations increases the productivity of arable land and contributes to the stabilization of soil fertility.

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