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Biologization And Efficiency Of Crop Rotation Types Under Conditions Of The Forest-Steppe Zone Of The Volga Region.

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ABSTRACT

The article is devoted to the study of the efficiency of practices of biologization of crop rotation types under conditions of the forest-steppe zone of the Volga region. It has been found that cereal and grass crop rotation types are more productive in the amount of feed units but the cereal and fallow land rotation is more productive in grain yields. Combined soil cultivation has a greater advantage in the influence on the efficiency of crop rotation types, which increased the amount of feed units by 0,20-0,42 thousand and grain by 0,10-0,25 t / hectare in comparison with minimal soil cultivation that is explained by the improvement of moisture availability and phytosanitary condition in crops. Fertilization systems with manure and straw had an equivalent effect on the efficiency of the cereal and fallow land rotation. Cereal and grass crop rotation types in production of feed units increased the productive capacity of arable land in the fertilization system of straw + NPK compared to the system of manure + NPK. Under conditions of biologization of crop rotation types, the growth of the yielding capacity of grain crops and the yield of grain from one unit of area to the second rotation were found, which is primarily due to the improvement of agrophysical, hydrological and biological properties of the soil and the optimization of the phytosanitary situation of crops.

Keywords: biologization of farming, crop rotation, combined soil cultivation, organic and mineral fertilizers.

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IMPORTANCE

At a contemporary stage of development scientific agronomy rests on the biosphere paradigm of nature utilization which accounts for ecological problems that arose on the planet, – pollution of the environment, global warming, nitrate contamination, pesticide accumulation and etc. [1, 2]. Biologic farming emerged in the countries with the highest intensification of agriculture that is directed towards the reduction of negative consequences of irrational use of lands, soil cultivation, fertilizers and pesticides [3, 4, 5, 6].

It is clear that biogenic intensification requires the experimental verification under certain soil and climatic conditions for the purpose of creating optimum models of crop rotation types and their links which determines the importance of long-term studies of crop rotation, soil tillage and fertilizers, that is directed to an increase in the yielding capacity of crops on the basis of biologization of farming.

Objective of studies: a comparative assessment of the efficiency of field crop rotation types under biologization and influence of the main tillage operation and systems of fertilization on leached black soil of the forest steppe zone of the Middle Volga region.

Technique of studies. The comparative study of the yield of cereal and leguminous crops was conducted in the course of the three factor field experiment at Ulyanovsk State Agrarian University in the period from 2005 to 2015. The field experiment implied the study of 6-field crop rotation systems that have the following designs (Factor A):

1) cereal crop and fallow land: fallow land – winter wheat – spring wheat - peas – spring wheat – spring wheat;
2) cereal and grass with brome: peas – winter wheat – spring wheat + brome - brome - brome – spring wheat;
3) cereal and grass with alfalfa: vetch (lupine white) – winter wheat – spring wheat +alfalfa - alfalfa - alfalfa – spring wheat;
4) cereal and grass: vetch-oats for green manure (peas + lupine for seeds) – winter wheat – spring wheat – esparcet (brome + alfalfa) – esparcet (brome + alfalfa) – spring wheat.

In experimental crop rotation types the principal tillage operation was conducted in two technologies (Factor B): 1) combined in a rotation 2) minimal. The combined tillage operation was chosen as the control group (variant 1), that comprises the use of mouldboard and non-mouldboard ways with the elements of minimization.

Minimal cultivation (variant 2) differs from the control group in depth and intensity of the impact on the soil.

In the experimental crop rotation types, two fertilization systems of organic and mineral fertilizers were used (Factor C). In the period of 2005-2008 in the first 3 rotation types: 1) manure + NPK 2) straw + NPK in the 4th rotation 1) green manure + NPK 2) green manure + straw + NPK. During the second cycle of crop rotation types, a set of leguminous crops and fertilization systems were changed: 1) straw + NPK (planned efficiency of crop rotation types was 2.67-3.10 grain units); 2) straw + NPK (planned efficiency of crop rotation is 3.25-3.88 grain units).

Replication of the experiment is three times, the systematic lay-out by the method of split plots, the area of plots of the first order is 560 m^2, the second is 280 and the third is 140 m^2. The soil of the experimental plot is leached black soil of medium thickness, medium loamy. The studies were carried out according to generally accepted techniques [7, 8].

The factors of biologization: biological nitrogen of legumes, straw, stubble and root residues, organic and mineral fertilizer systems.

The years of studies were different in meteorological conditions, so year 1 (2005) was characterized by high moisture availability with the hydrothermic coefficient(HTC) of 1.46 units for May-June, 3 years were characterized by a lack of moisture with the HTC = 0.88-0.97 (2006, 2007 , 2013), an average drought with the HTC = 0.46-0.55 (2008, 2015) was observed for 2 years and a mild drought with the HTC of 0.62 (2012 and

2014) was observed for 2 years. The analysis of meteorological conditions shows their sharp contrast with prolonged soil and air droughts in some periods and excessive moisture levels in others.

RESULTS AND ITS DISCUSSION

The efficiency of biologized crop rotation systems under conditions of the forest-steppe zone of the Volga region can be seen from the data in Table 1. The analysis of the yield of perennial grasses during the first rotation for the collection of feed units showed the advantage of alfalfa - 6.05-7.14 t / ha, which is higher in comparison with esparcet by 1,34-1,83 t / ha and with brome by 1,61-1,96 t / ha (Table1).

According to the amount of the conditional feed units, the crop rotation types studied were distributed in the following order: cereal-grass with alfalfa-4,67 thousand from 1 ha, cereal-grass with brome-3,82, cereal-grass with esparcet-3,73 thousand / ha and cereal-fallow land crop rotation - 2, 90 thousand / ha. Differences are due to a high yielding capacity of perennial grasses in comparison with other crops studied.

According to the yield of grain from 1 hectare of arable land the cereal and fallow land crop rotation had the advantage owing to a high concentration of cereals - 83% of the crop rotation area. On average for 2005-2008 the yield of grain from 1 hectare here was 2.36 tons. At the same time, combined soil cultivation ensured an increase in the collection of grain in comparison with the minimal system by 0.25 t / ha. Fertilization systems of manure + NPK and straw + NPK were equivalent in the influence on the crop formation and yielding capacity in the cereal and fallow land rotation.

In crop rotation types with a cereal crop share of 67%, the cereal and grass rotation with alfalfa had the advantage in the grain yield - 1.77 t / ha whereas the grain yield in the rotation with brome grass was 1.70 t / ha. The effect and aftereffect of combined soil cultivation in a crop rotation was higher than in comparison with the minimal one, and the fertilization systems studied were equivalent in their influence on the yield of grain from 1 hectare.

With a decrease in the share of grain crops to 50% in a cereal and grass rotation with fallow land after application of green manure (cereal-grass with esparcet), the yield of grain decreased to 1.47 t / ha.

The evaluation of the effect of fertilization systems showed a significant increase in the yield of alfalfa and esparcet according to the variants of the experiment where straw had been applied. The increase in the yielding capacity is due to an increase in the activity of legume-rhizobium symbiosis and the efficiency of nitrogen fixation of alfalfa, esparcet and leguminous crops.

The consistent patterns of crop formation, depending on the soil cultivation systems, were the same as in other cereal-grass rotation types. During the first rotation of crop rotation types, the fertilization system of green manure + straw + NPK had an advantage over the fertilization system of green manure + NPK in terms of their efficiency.

Soil cultivation is one of the significant factors that have influence on the conditions of growth of cultivated plants due to the impact on the agrophysical properties of the soil, microbiological activity and phytosanitary state of seedlings.

Soil cultivation is one of the significant factors affecting the conditions of growth of cultivated plants due to the impact on the agrophysical properties of the soil, microbiological activity and phytosanitary state of crops.

We have found that the combined system compared with the minimal one had an advantage in terms of the effect on the yield of cereals, leguminous crops, perennial grasses and, in general, on the efficiency of the crop rotation systems studied. According to our data, on the average for experimental crop rotations, the increment was 0.20 thousand / ha of feed units and 0.12 t / ha of grain in favor of combined soil cultivation. Its advantage was especially manifested in crop rotation systems with perennial grasses, which reduced yields without plowing.

Differences in the crop rotation efficiency are explained not only by the range of crops with different

yield potentials, but also by the effect of alternating crops on the phytosanitary state of crops, performing a phytosanitary function.

On the average on the fields in the first rotation(cycle) of crop rotation types, the least amount of weeds, both at the beginning of vegetation and before harvesting, was recorded in the cereal-grass rotation - 23.6 pcs / m^2 and 22.1 pcs / m^2, respectively, with their air-dry weight of 4, 5 and 31.1 g / m^2. The greatest weed infestation was found in a cereal-grass rotation with esparcet - 37.1-36.0 pcs / m^2 with a weight of 13.7-40.4 g / m^2. Rotation types with brome and alfalfa took an intermediate position.

In the years of the second rotation, a somewhat different phytosanitary situation developed on the fields with crop rotation. On average in a crop rotation, the lowest number of weeds was registered in cereal-grass rotation types with a brome and grass mixture (brome + alfalfa) in the spring - 18.3-16.8 pcs / m^2 and 18.8-17.6 pcs / m^2 before harvesting, with the weight of 9.2-9.5 and 20.7-18.8 g / m^2 respectively. On the fields of the cereal and fallow land rotation, on average, there were 20.2 pcs / m^2 in the spring, and before harvesting this number was 21.6 pcs / m^2 with a weight of 6.4 and 23.6 g / m^2, respectively, according to the observation terms.

By the second rotation there had been a decrease in the weed infestation in comparison with the first rotation. For instance, in the variant of a cereal-fallow land rotation, the weed infestation was lower by 13.1% in spring and by 2.7% before harvesting, in cereal-grass rotation types it was even lower by 23.2-49.3% and 4.5-51.1% according to the terms of their identification. The same situation was formed in the weight of weed plants. Before harvesting, the weight of weed plants decreased by 15.7-53.1% compared to the first rotation.

Along with the predecessors, soil cultivation plays an important role in regulating the weed component of agrophytocenosis. According to our data, in the period of the first rotation of crop rotation types, combined soil cultivation contributed to a reduction in the weed infestation. On average in crop rotation types, before harvesting 22.2 pcs / m^2 of weeds were registered in the variant of combined soil cultivation, and in the minimal soil cultivation - 29.4 pcs / m^2, and their biomass increased from 26.0 to 37.8 pcs / m^2 . The similar data were obtained during the second rotation of crop rotation types.

It should be noted that in biologized crop rotation, both in the first and second cycles of crop rotation types, weeds did not exceed the average level of the weed infestation, whereas in the fields of the region the number of weeds considerably exceeded the economic damage thresholds [10, 11].

Thus, our studies showed the weed-removing ability of crop rotation types, especially with perennial grasses, which are highly competitive with the weed component of agrophytocenosis. In addition, many authors note that during the growth of individual crops (lupine), as well as in the decomposition of the root-crop residues of perennial grasses, physiological substances are released into the soil (allelopathic action), which have an inhibitory effect on germination of seeds and vegetative propagation organs of weed plants [12, 13].

During the second rotation period, the consistent patterns observed in the evaluation of the efficiency of the cereal and fallow land rotation, the cereal and grass rotation with brome, the cereal and grass rotation with alfalfa and the cereal and grass with grass mixture (brome+lupine) during the first rotation were preserved.

The studies have shown that the cereal and fallow land rotation was prominent in the grain yield with a grain concentration of 83%, where the grain yield was 2.57 t / ha, which is 8.9% more than during the first rotation. In the crop rotation types with a share of grain crops of 67% (cereal and grass) this index was at the level of 1.83-1.85 t / ha or 4.5-8.2% higher than in the period of the first rotation (Table 2).

The replacement of the fallow land with green manure in the IV crop rotation by the mixture of lupine + peas (grain) resulted in an increase in the grain yield up to 1.83 t / ha or 24.5%.

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More complete use of fertilizers was observed in the first organic and mineral fertilization system, planned for the efficiency of crop rotation of 3.06-4.11 thousand feed units per 1 ha. The use of increased doses of fertilizers from the soil and a more complete realization of the cropping power potential were limited due to arid conditions of spring-summer periods. We have revealed a direct relationship between the efficiency of crop rotation types and the hydrothermal coefficient for May-June by years (r = 0.52-0.75).

Table 1: Comparative efficiency of crop rotation types for 2005-2008 (first rotation)

Design of crop rotation (Factor A)	Soil tillage (Factor B)	Fertilizers (Factor C)	Yielding capacity of grain and leguminous crops, t/ha	Cropping power of perennial grasses, thous./ha of feed units	Total amount from 1 ha of seedbed in a crop rotation				
					of feed units, thous.			of grain, t	
					By factors				
					C	A	B	A	B
Fallow land – winter wheat – spring wheat – peas – spring wheat – spring wheat	B_1	Manure + NPK	2,98	-	3,06	2,90	3,05	2,36	2,48
		Straw + NPK	2,97	-	3,04				
	B_2	Manure + NPK	2,69	-	2,74		2,74		2,23
		Straw + NPK	2,67	-	2,73				
Peas- winter wheat- spring wheat – кострец – кострец- spring wheat	B_1	Manure + NPK	2,71	4,73	3,90	3,82	4,00	1,70	1,80
		Straw + NPK	2,70	5,18	4,09				
	B_2	Manure + NPK	2,41	4,35	3,52		3,63		1,61
		Straw + NPK	2,41	4,72	3,75				
Vetch – winter wheat – spring wheat – lucerne – lucerne – spring wheat	B_1	Manure + NPK	2,80	6,65	4,78	4,67	4,88	1,77	1,86
		Straw + NPK	2,78	7,14	4,98				
	B_2	Manure + NPK	2,53	6,05	4,42		4,46		1,67
		Straw + NPK	2,49	6,33	4,50				
Mean values in crop rotation types		Manure + NPK	**2,69**	**5,45**	**3,74**				
		Straw + NPK	**2,67**	**5,84**	**3,85**				
Vetch-oats for green manure – winter wheat – spring wheat – esparcet – esparcet – spring wheat	B_1	Green manure + NPK	3,10	5,07	3,82	3,73	3,88	1,47	1,55
		C + C+ NPK	3,11	5,31	3,94				
	B_2	Green manure + NPK	2,79	4,71	3,50		3,58		1,39
		C + C+ NPK	2,78	5,10	3,67				
Mean values in a crop rotation		Green manure + NPK	**2,95**	**4,89**	**3,66**				
		C + C+ NPK	**2,95**	**5,21**	**3,81**				
LSD_{05} for particular mean values = 0,20			-	-	0,09	0,11	0,09	-	-

B_1 – combined; B_2 – minimal

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Table 2: Comparative efficiency of crop rotation types for 2012-2015 (second rotation)

Design of crop rotation (Factor A)	Soil tillage (Factor B)	Fertilizers (Factor C)	Yielding capacity of cereals and leguminous crops, t/ha	Cropping power of perennial grasses, thous./ha of feed units	Total amount from 1 ha of seedbed in a crop rotation				
					of feed units, thous.			of grain, t	
					C	A	B	A	B
Fallow land – winter wheat – spring wheat – peas – spring wheat – spring wheat	B_1	C+ $N_{22}P_{23}P_{23}$	3,05	-	3,15				
		C+ $N_{43}P_{35}K_{35}$	3,28	-	3,38		3,27		2,65
	B_2	C+ $N_{22}P_{23}P_{23}$	2,86	-	2,96				
		C+ $N_{43}P_{35}K_{35}$	3,08	-	3,18	3,17	3,07	2,57	2,49
Peas – winter wheat- spring wheat – brome – brome- spring wheat	B_1	C+$N_{27}P_{27}K_{27}$	2,74	4,04	3,61				
		C+$N_{53}P_{33}K_{33}$	2,95	4,34	3,89		3,75		1,90
	B_2	C+$N_{27}P_{27}K_{27}$	2,55	3,72	3,36				
		C+$N_{53}P_{33}K_{33}$	2,78	4,06	3,65	3,63	3,51	1,84	1,78
Lupine – winter wheat – spring wheat – alfalfa – alfalfa – spring wheat	B_1	C+$N_{20}P_{25}K_{25}$	2,75	4,38	3,77				
		C+$N_{40}P_{38}K_{38}$	2,94	4,72	4,04		3,91		1,90
	B_2	C+$N_{20}P_{25}K_{25}$	2,61	3,99	3,52				
		C+$N_{40}P_{38}K_{38}$	2,77	4,30	3,77	3,78	3,65	1,85	1,80
Lupine + peas – winter wheat – spring wheat – brome +alfalfa – brome + alfalfa – spring wheat	B_1	C+$N_{20}P_{25}K_{25}$	2,72	4,28	3,69				
		C+$N_{40}P_{38}K_{38}$	2,92	4,59	3,96		3,83		1,88
	B_2	C+$N_{20}P_{25}K_{25}$	2,58	3,98	3,47				
		C+$N_{40}P_{38}K_{38}$	2,77	4,19	3,70	3,71	3,59	1,83	1,78
In factor C			**2,74**	**4,07**	**3,44**	-	-	-	-
			2,94	**4,36**	**3,70**	-	-	-	-
LSD_{05} for particular mean values = 0,26			-	-	0,12	0,15	0,12	-	-

B_1 – combined; B_2 – minimal

Attention should be paid to the increase in the yielding capacity of grain crops and grain efficiency of the crop rotation types studied from the first to the second rotation of biologized crop rotation types. This happened under the conditions of decreasing precipitation during the growing season. We can assume that the increase in the yielding capacity of cereals by the second rotation was due to the increase in the doses of mineral fertilizers (appendices 4 and 5), but this fact does not give a full explanation, since under conditions of insufficient moisture levels perennial grasses reduced their yielding capacity.

The growth of the yielding capacity and productivity of cereals and leguminous crops is due, above all, to the improvement of the agrophysical, hydrological and biological properties of the soil. In addition, the phytosanitary tension in crops was decreasing, a decrease in the weed infestation to the second rotation of crop rotations and a decrease in the development of root rot of cereal crops in grain-crop rotations were observed.

Thus, crop rotation is an important system-forming link in the system of biologization of agriculture. It gives an opportunity to diversify agricultural production and ensure the rational use of natural and anthropogenic factors of crop formation within agroecosystems, to plan soil cultivation systems and fertilizers, while enhancing phytosanitary and ecological functions.

CONCLUSIONS

1. Comparative efficiency of crop rotation types in the yield of feed units has showed that in their yielding capacity they can be placed in the following row: cereal and grass with alfalfa – 3,78-4,67 thous./ha, cereal and grass with brome - 3,63-3,82, cereal and grass with esparcet - 3,73 thous./ha, cereal and grass with a grass mixture - 3,71 thous./ha and cereal and fallow land rotation - 2,90-3,17 thous./ha. Differences in the cropping power are explained by a high yielding capacity of perennial grasses, which more efficiently utilized bioclimatic potential.

2. The grain yield in crop rotation types was determined by the concentration level of grain and leguminous crop seedlings. The biggest yield of grain was found in a cereal and fallow land rotation with the share of cereal and leguminous crops of 83 % - (2,36 t/ha), with the second rotation the efficiency of a crop rotation increased by 8,9% (2,57 t/ha). The growth of the grain yield from a unit of area and in cereal and grass rotation types was observed.

3. In all types of crop rotation, combined soil cultivation had an advantage in the influence on the yield of grain crops, perennial grasses and leguminous crops, which increased the amount of feed units by 0.20-0.42 thousand and the grain yield by 0.10-0.25 t / ha, which is explained by improved mosture availability and improved phytosanitary condition of crops.

4. Fertilization systems with manure and straw had an equivalent effect on the efficiency of the cereal and fallow land rotation. Cereal and grass rotation types in the output of feed units increased the utilization efficiency of arable land in contrast to the fertilization system of straw + NPK compared to the system of manure + NPK. The latter is explained by an increase in the efficiency of legume-rhizobia symbiosis when straw is used as a fertilizer, which in turn increases the cropping power of perennial leguminous grasses and grain legumes, and had an effect on the harvesting of crops in a crop rotation. A similar picture was formed in the evaluation of fertilization systems, green manure + NPK and straw + green manure + NPK - the second fertilization system increased the efficiency of a cereal-grass rotation in the amount of feed units.

5. During the second rotation of crop rotation types, the abovementioned patterns were preserved, an increase was found in the yield of cereals compared with the first rotation, and the advantage of the fertilization system of straw + NPK for the planned yielding capacity of 3,06-4,11 thousand of feed units was revealed. The underutilization of increased fertilizer doses from the soil for a more complete realization of yield potential was limited due to arid conditions of spring-summer periods. We have revealed a direct relationship between the efficiency of crop rotation types and the hydrothermal coefficient for May-June by years (r = 0.518-0.744).

6. Under conditions of biologization of crop rotation, the yield of grain crops and the yield of grain from a unit of area in the first and the second rotation were found, which is explained, first of all, by improving the agrophysical, hydrological and biological properties of the soil and optimizing the phytosanitary condition of sown crops.

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