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Experimental bases of crop productivity depending on agrotechnical conditions

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Abstract. As a result of the research, experimental data were obtained on the yield of cultivated crops depending on the type of crop rotation, fertilizer and treatment systems, and their mutual effect on improving ALSZ on the soils of the Vladimir high plain. The main types of fertilizer systems and their effect on the yield of grasses in crop rotation are described. Experimental data have been used to study the effect of various fertilizer systems on productivity, density, botanical composition, and yield of perennial grasses. It is proved that the yield parameters directly depend on the specific tillage system. The effect of fertilizer doses on the yield and productivity of perennial grasses for 2 years of use was revealed.

1 Introduction

The preservation and increase of the fertility of gray forest soils, characterized by its low natural indicators and properties, is one of the urgent agricultural production problems.

In the conditions of the Vladimir high plain, there are no restrictions on the cultivation of zoned crops on the uplands. On the uplands, perennial leguminous grasses are cultivated to obtain nutritious feed, in addition, they are a good precursor for most crops. They enrich the soil with biological nitrogen, improve the soil structure, and saturate the crop-root residues.

On erosive lands, the positive role of perennial grasses increases. They favorably affect the soil structure, its water-retaining properties increase and thus wash is prevented. On semi-hydro-morpho-zonal lands, perennial grasses should also be cultivated, which are an effective way of reclamation.

The purpose of the research: to study the effect of fertilizer systems on the productivity of grasses for 2 years of use on gray forest soils of the Vladimir high plain.

Research objectives: to study the density of standing plants of perennial grasses and the effect of the fertilizer system on nitrate nitrogen reserves and the content of mobile phosphorus and exchangeable potassium in the phases of growth and development under perennial grasses for 2 years of use. To determine the fertilizer system effect on the yield of hay of perennial grasses for 2 years of use.

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In the current conditions, to obtain high productivity of crops of perennial grasses, it is necessary to observe the correct agricultural techniques: tillage system, fertilizer system, as well as crop rotation. Perennial grasses are easily included in the crop rotation. It can be grown before and after all cultivated plants except for itself [1]. In all major regions of the European part of Russia, perennial grasses are planted under the cover of spring and winter cereals, as well as annual grasses. Sowing perennial grasses under cover has a great economic advantage, as it ensures a normal harvest of the cover crop.

Due to the large amount of nitrogen and plant residues remaining in the soil, good penetration of the root system and physical ripeness of the soil, after cultivation, clover is a good precursor for many crops and has a healing effect on crop rotation. But a positive role in the crop rotation of perennial grasses is played when the crops are thick and not clogged. Clogged crops of perennial grasses, which are often found during long-term cultivation, are a poor precursor [2].

In the conditions of the Vladimir high plain there are three directions of tillage: dump system, non-dump system with the use of deep diggers, flat cutters and disk tools, two-tier plowing in combination with other tillage tools.

The use of two-tier plowing on gray forest soils of the Vladimir high plain provides an increase in yield up to the fifth crop inclusively. The increase in hay of perennial grasses is 1.8-2.59 and 1.06-1.7 t/ha.

The main tillage of the soil for cover crop is at the same time its preparation for sowing perennial grasses. Winter preliminary stubble ploughing for spring cover crop is an important condition for obtaining a high and stable yield of perennial grasses. The tasks of pre-sowing treatment are careful leveling and rolling of the soil to restore capillary bonds and place seeds at the same depth, which increases the field germination of seeds.

In ALSZ projects, a landscape approach to the distribution and use of fertilizers is carried out considering relief, soil cover structure, soil washout, etc.

The introduction of fertilizers is one of the more effective rapidly functioning tools for supplying plants with components of feeding and increasing soil fertility. But the productivity of fertilizers in a significant proportion depends on their correct use, which guarantees the best match of mobile nutrients in the soil. The excess and shortage of components negatively have a great impact on the quality of the crop and lead to a decrease in the likely land fertility [3]. A. V. Sokolov observed that the effectiveness of plants depends not only on the number, but also on the nature of the distribution of digestible nutrients in the soil.

To date, resource-saving technological crop cultivation processes have been extensively used in agriculture.

2 Materials and Methods

The task of the experiment study includes the study of five links of six-field crop rotations on four backgrounds of the tillage system (table1).

Table 1. Scheme of crop rotation links in the experiment.

1 crop rotation	2 crop rotation	3 crop rotation	4 crop rotation	5 crop rotation
Oats + gr.	Oats + gr.	Barley + gr.	Barley + gr.	Barley + gr.
Per. gr. 1 y.u.	Per. gr. 1 y.u.	Per. gr. 1 y.u.	Per. gr. 1 y.u.	Per. gr. 1 y.u.
Per. gr. 2 y.u.	Per. gr. 2 y.u.	Per. gr. 2 y.u.	Per. gr. 2 y.u.	Peas+oats
Barley	Spring wheat	Winter rye	Winter wheat	Winter wheat
Dead fallow	Ann. grasses	Spring wheat	Potato	Legumes
Winter wheat	Winter wheat	Oats	Spring wheat	Spring wheat

1. Generally accepted moldboard (traditional)
2. Combined energy-saving
3. Combined-tiered
4. Anti-erosion

Four intensification levels were studied:

1. Zero (extensive) – for productivity – 18-20 c g. u/ha.
2. Supportive (normal) – for productivity – 20-23 c g. u/ha.
3. Intensive – for productivity – 27-35 c g. u/ha.
4. High–intensity – for productivity - 37-45 c g. u/ha.

These levels are created at the expense of calculated doses of fertilizers:

1. Zero (extensive) – without fertilizers
2. Supporting (normal) - $N_{30}P_{30}K_{30}$
3. Intensive - $N_{60}P_{60}K_{60}$
4. High-Intensity - $N_{90}P_{90}K_{90}$

The experiment is located on an area of 2.4 hectares. The experiment was laid in 4-fold repetition on 4 tillage systems. The arrangement of options by blocks and tiers is systematic. The plot area is 20 m * 7 m = 140 m^2.

The following calculations and observations were carried out in the experiment: The dynamics of productive moisture reserves for all variants of experiments; The dynamics of nitrate nitrogen reserves in a layer of 0-40 cm for all options of experiments; Crop accounting by the parcel method for all options of experiments.

In 2022, observations and records were carried out on the third crop (perennial grasses 2 y.u.).

The content of nitrate nitrogen, mobile phosphorus, exchangeable potassium and pH was determined according to generally accepted methods. Statistical processing was performed according to the STATISTICA 6.0 program.

The growing season of 2022 was generally characterized as favorable for the growth and development of perennial grasses of 2 y.u. and annual grasses. The average air temperature for the growing season of 2022 was slightly lower (by 0.4°C) compared to the average long-term data, and without sharp fluctuations during the entire period, the difference between the indicators does not exceed 3.5 C.

According to moisture availability, the Vladimir high plain belongs to the zone of the washing type of water regime, where in the spring period there is complete soaking of the soil with the possibility that dry conditions may develop in 25% of the time during the growing season, and in 10% there is a summer drought. The average annual precipitation for the year is 604 mm with fluctuations over the years from 414.6 to 741 mm. The amount of precipitation during the growing season was 117% of the norm. During the phase of active regrowth and appearance of lateral shoots, excessive precipitation was observed (the first, second, and third decades of May at 34.8, 21.5, and 34.8 mm) at lower average daily temperatures (8.9, 9.0, and 12.9°C), which favorably affected the growth and development of perennial and annual grasses. In the first decade of July, the amount of precipitation was 2.7 times higher than normal, which led to a slight delay in harvesting herbs.

In general, the weather conditions of spring-summer 2022 were favorable for obtaining high yields of perennial and annual grasses. During the growing season, studies were conducted on the dynamics of productive moisture reserves up to one meter, every 20 cm. Sampling was carried out at all crop rotations (during the phase of vegetation renewal (shoots of annual grasses), branching and budding, after harvesting). In the phase of renewal of vegetation of perennial grasses of 2 y.u., the soil with combined-tiered treatment in the third and fourth crop rotation was more saturated with productive moisture reserves in the 0-20 cm layer – 40.6 and 40.0 mm, respectively.

3 Results and Discussion

According to the gradation of productive moisture reserves for the growth of crops in a layer of 0-20 cm, productive moisture reserves of 40 mm are considered good. On annual grasses in the germination phase, plots with anti-erosion - 36.5 mm and combined-tiered tillage - 35.7 mm were more saturated with productive moisture.

The least reserves of productive moisture were on combined energy-saving tillage both on grasses of 2 y.u. and on annual grasses: from 30.7 mm in the first and third crop rotation to 33.4 mm in the second and 32.3 mm, respectively. According to the reserves of productive moisture in the 0-40 cm layer, the same trend is observed as in the 0-20 cm layer . Furrow and combined tiered tillage are more saturated with productive moisture (76.8mm) than anti-erosion (72.2mm) and energy-saving (67.7mm) tillage systems, on annual grasses, combined tiered and furrow tillage are also more saturated with productive moisture (76.8 and 75.0 mm, respectively) than on anti-erosion and combined energy-saving – 62.2 and 62.7 mm. That is, deep tillage retains moisture better than surface loosening.

At the beginning of the growing season, in the renewal phase, the reserves of productive moisture in the meter-long soil layer varied from 155.3 mm on combined-energy-saving tillage to 192.3 mm on the furrow one in the fourth crop rotation; on annual grasses in the germination phase, the reserves of productive moisture in the meter-long soil layer varied from 165.1 mm on combined-energy-saving to 179.9 mm on combined-tiered . That according to the gradation of productive moisture reserves for the growth of crops in a layer of 0-100 cm is also considered good (productive moisture reserves of 160-139 mm). During the branching phase and the beginning of budding, moisture reserves decreased by an average of 30-45%, this is directly related to the absence of precipitation during this period, soil weathering and consumption by plants, they ranged from 94.1 mm in the second crop rotation to 135.1 mm in the first; on annual grasses from 113.9 mm on anti-erosion tillage to 129.3 mm on furrow one.

After harvesting, moisture reserves in the meter layer increased due to the cessation of vegetation and precipitation and ranged from 142.4 to 168.7 mm on perennial grasses of 2 y.u., on annual grasses from 142.9 mm on the furrow to 151.0 mm. As observations of productive moisture content have shown, soils with deep loosening (generally accepted furrow and combined-tiered tillage), used both on perennial and annual grasses, are more saturated. The uniform distribution of moisture reserves over a meter layer of soil should also be noted.

When examining the crops of perennial grasses of 2 y.u. after overwintering, the following pattern was revealed: the regrowth of plants on low fertilizer backgrounds is more friendly, but the crops are sparse (1 and 2 crop rotations), the reverse trend on high fertilizer backgrounds (crop rotations 3 and 4).

Crop yields are largely determined by the presence of available nutrients in the soil. The most reliable indicator of the availability of plants with available forms of nitrogen is the nitrate nitrogen content in the soil. The content of nitrate nitrogen in the arable soil layer is not constant and depends on many factors (weather conditions, soil aeration, humus content, etc.). Studies show that nitrogen fertilizers applied have a direct effect on nitrate nitrogen content in the soil (Table 2).

Table 2. Effect of tillage and fertilizer systems on nitrate nitrogen reserves under perennial grasses of 2 y.u. in the soil layer of 0-40 cm, kg/ha of soil.

Soil tillage	Vegetation phases	Fertilizer systems		
		without fertilizers	$N_{60}P_{60}K_{60}$	$N_{90}P_{90}K_{90}$
Surface loosening anti-erosion, energy-saving)	Resumption of vegetation	10.3	16.0	17.9
	After harvesting	11.4	17.4	22.6
Furrow	Resumption of vegetation	12.7	14.4	24.4
	After harvesting	13.8	24.1	24.4

Thus, their content increased with an increase in the applied dose of fertilizers: in the phase of vegetation resumption from 10.3 without the use of fertilizers to 17.9 kg/ha of soil on a high-intensity background with surface loosening, on deep tillage from 12.7 to 24.4 kg/ha of soil, respectively. After harvesting from 11.4 to 22.6 kg/ha of soil on surface loosening and 13.8 and 24.4 kg/ha on deep one. An increase in the nitrate nitrogen content in the soil after harvesting is associated with the cessation of vegetation, as well as with humidification conditions and temperature regime of soils. The content of mobile phosphorus and exchangeable potassium in the soil layer of 0-20 cm on cultivated crops increases with increasing doses of fertilizers, this increase also affects the sub-arable layer of 20-40 cm. In 2022, the effect of fertilizer systems and soil tillage was not traced, the values of mobile phosphorus indicators were aligned by intensity levels, with minor changes during the growing season (Table 3).

Table 3. The effect of tillage and fertilizer systems on the content of mobile phosphorus (P_2O_5) by the growth phases of perennial grasses 2 y.u., mg/kg of soil.

Soil tillage	Vegetation phases	Fertilizer systems		
		without fertilizers	$N_{60}P_{60}K_{60}$	$N_{90}P_{90}K_{90}$
In the arable horizon 0-20 cm				
Deep loosening (furrow, tiered)	Resumption of vegetation	126	162	141
	After harvesting	142	158	164
In the sub-arable horizon of 20-40 cm				
Deep loosening (furrow, tiered)	Resumption of vegetation	128	143	137
	After harvesting	151	126	133

The mobile phosphorus content in surface loosening is slightly lower than in deep loosening at all levels of intensity except for treatments without the use of mineral fertilizers. The change in the indicators of potassium exchange in the arable horizon of 0-20 cm depends directly on the fertilizer systems, thus, from the phase of vegetation resumption to the phase after harvesting, there is a noticeable decrease, on the surface loosening from 210 to 187 mg/kg of soil, on the deep from 254 to 209 mg/kg of soil, whereas the indicators on the background without fertilizers they are kept in values close to each other. Observation of the content of exchangeable potassium in the crops of perennial grasses revealed the following pattern: in the soil layer of 20-40 cm, the indicators of exchangeable potassium content have not changed significantly, and the effect of soil treatments and fertilizer systems is not traced (Table 4).

Table 4. The effect of tillage and fertilizer systems on the content of exchangeable potassium (K_2O) by the growth phases of perennial grasses 2 y.u., mg/kg of soil.

Soil tillage	Vegetation phases	Fertilizer systems		
		without fertilizers	$N_{60}P_{60}K_{60}$	$N_{90}P_{90}K_{90}$
In the arable horizon 0-20 cm				
Deep loosening (furrow, tiered)	Resumption of vegetation	170	254	248
	After harvesting	197	209	245
In the sub-arable horizon of 20-40 cm				
Deep loosening (furrow, tiered)	Resumption of vegetation	141	146	149
	After harvesting	173	200	177

The increase in the content of mobile phosphorus and exchangeable potassium in plots without mineral fertilizers can be explained by the fact that the plots are located on a site with a slope of 3o, which during the rainy season at the beginning of the growing season (117% to the norm) led to the leaching of mobile phosphorus from neighboring plots where mineral fertilizers were used. One of the most important indicators of the physico-chemical properties of soils is the reaction of the medium. A favorable value is the soil medium reaction – one of the determining conditions for obtaining high yields of cultivated crops (Table 5).

Table 5. Effect of treatment and fertilizer systems on soil acidity, pH.

Soil tillage	Vegetation phases	Fertilizer systems		
		without fertilizers	$N_{60}P_{60}K_{60}$	$N_{90}P_{90}K_{90}$
In the arable horizon 0-20 cm				
Deep loosening (furrow, tiered)	Resumption of vegetation	5.43	5.10	5.30
	After harvesting	5.41	5.19	5.24
In the sub-arable horizon of 20-40 cm				
Deep loosening (furrow, tiered)	Resumption of vegetation	5.15	5.10	5.40
	After harvesting	5.33	5.15	5.46

Studies in 2022 showed that due to the high buffer properties of the absorbing complex of gray forest soils of High field and the multidirectional factors affecting acidity, no significant effect of the main elements of adaptive landscape farming systems on the change in the acidity of the studied ones was revealed. The indicators of soil acidity are more leveled, the difference between the maximum (5.57) and minimum (5.10) is not significant, with an average (5.33).

The intensification level significantly affected the yield of perennial grasses of the second year of use. In the first crop rotation without the use of fertilizers, the average yield of hay of perennial grasses of 2 y.u was 53.9 c/ha. The aftereffect of the use of mineral fertilizers at a maintenance level of 30 kg of a.d. of nitrogen, phosphorus, and potassium, under cover crop led to an increase in the yield of perennial grasses of 2 y.u., the average yield of hay of perennial grasses was 55.1 c/ha. In the second crop rotation, the yield was higher than in the first one, the maximum yield was obtained at an intensive level of 60 kg of nitrogen, phosphorus, and potassium for the cover crop and amounted to 59.5 c/ha of hay. In the third and fourth crop rotation, as the intensity increased, the yield of perennial grasses of 2 y.u. increased. The difference in yield is significant for pairs of the third and first; and the fourth and first crop rotations. Annual furrow treatment is the least effective method of basic treatment for the cover crop of perennial grasses (53.7 c/ha of hay). The maximum yield of hay was obtained on combined-tiered processing – 63.3 c/ha. The difference is significant for pairs of combined tiered-anti-erosion, combined-energy-saving anti-erosion, generally accepted furrow-combined tiered. This year, a significant increase in the yield of hay of perennial grasses of 2 y.u. was revealed, due to an increase in the intensity of crop rotation with an increase in the doses of organomineral and mineral fertilizers for the cover crop, there is an increase in the yield of hay of perennial grasses of 2 y.u. (from 53.9 to 62.4 c/ha).

The increase in the yield for tillage to the generally accepted furrow one was from 1.8 c/ha of hay on anti-erosion treatment, to 6.9 c/ha of hay on combined-tiered.

The aftereffect of the use of fertilizers also played a role in increasing the yield of grasses of 2 y.u.: compared with the yield of clover hay on plots without fertilizers, the increase with the use of fertilizers ranged from +0.9 c/ha of hay on a supportive background with the introduction of 30 kg of a.d. in the second crop rotation to +13.9 c/ha of hay of perennial grasses on intensive background (60 kg of a.d.) in the fourth crop rotation. On the fifth crop rotation, a pea-oat mixture was sown.

In terms of yield and fodder value, cereal grasses are inferior to leguminous grasses, their joint cultivation increases the overall yield of grass mixtures, hay obtained from grass mixtures of legumes and grasses is harvested with less losses, it is better preserved compared to hay from legumes (Table 6).

Table 6. Botanical composition of components of annual herbs, %.

<table>
<tr><th rowspan="3">Fertilizer doses</th><th colspan="12">Tillage</th></tr>
<tr><th colspan="3">Anti-erosion</th><th colspan="3">Combined-tiered</th><th colspan="3">Combined-energy-saving</th><th colspan="3">furrow</th></tr>
<tr><th>Legumes</th><th>Cereals</th><th>Motley grass</th><th>Legumes</th><th>Cereals</th><th>Motley grass</th><th>Legumes</th><th>Cereals</th><th>Motley grass</th><th>Legumes</th><th>Cereals</th><th>Motley grass</th></tr>
<tr><td>$N_{60}P_{60}K_{60}$</td><td>68.5</td><td>30.1</td><td>1.4</td><td>59.9</td><td>39.0</td><td>1.21</td><td>69.5</td><td>29.7</td><td>0.8</td><td>65.3</td><td>33.5</td><td>1.2</td></tr>
<tr><td>$N_{90}P_{90}K_{90}$</td><td>59.6</td><td>38.6</td><td>1.8</td><td>56.3</td><td>42.5</td><td>1.2</td><td>65.3</td><td>33.9</td><td>0.8</td><td>54.3</td><td>44.3</td><td>1.4</td></tr>
</table>

The analysis of the species composition of the annual herb harvest showed that the factors studied in the experiment had an unequal effect on the growth and development of pea and oat. Thus, on anti-erosion and combined-energy-saving tillage (surface loosening), the content of the legumes component is higher than on deep tillage (combined-tiered and conventional furrow): 64.1-67.4% and 58.1-59.8% respectively. Weeds are the least on the combined energy-saving tillage of 0.8%. The intensity level and tillage did not significantly affect the yield of hay of annual grasses. On average, the crop rotation yield of hay of annual grasses was 61.9 c/ha. The use of mineral fertilizers at an intensive level (60 kg of a.d. of phosphorus and potassium nitrogen) led to an increase in the yield of hay pea mixture – 62.1 c/ha compared with a high-intensity level (up to 90 kg of a.d. of phosphorus and potassium nitrogen) - 61.7 c/ha. On average, according to the fifth crop rotation, the yield of the pea-oat mixture was 61.9 c/ha, a slight decrease in yield on combined teired processing was 59.9 c/ha. On grasses of 2 years of use, when using a high-intensity background of mineral fertilizers, yields decrease compared to an intensive background. This is due to the weather features of the growing season of 2017 (high precipitation at the beginning of the growing season), obviously this dose did not inhibit the development of the legumes component, which provided the herbage with symbiotic nitrogen.

4 Conclusion

The reserves of productive moisture at the beginning of the growing season were sufficient for the growth of crops, but during the flowering phase decreased by an average of 30%. The decrease in the reserves of productive moisture in the soil is associated with its consumption by plants during the flowering period and insufficient soil moisture during this period. After mowing, moisture reserves in the meter layer increased due to precipitation and ranged from 142.4 to 168.7 mm. Soils with deep loosening (generally accepted furrow and combined-tiered tillage), used both on perennial and annual grasses, are more saturated. The uniform distribution of moisture reserves over a meter layer of soil should also be noted. The applied nitrogen fertilizers have a direct effect on the nitrate nitrogen content in the soil. Thus, their content increased with an increase in the applied dose of fertilizers: in the phase of vegetation resumption from 10.3 without the use of fertilizers to 17.9 kg/ha of soil on a high-intensity background with surface loosening, on deep tillage from 12.7 to 24.4 kg/ha of soil, respectively. After harvesting from 11.4 to 22.6 kg/ha of soil on surface loosening and 13.8 and 24.4 kg/ha on deep one. An increase in the nitrate nitrogen content in the soil after harvesting is associated with the cessation of vegetation, as well as with humidification conditions and temperature regime of soils. The content of mobile phosphorus, exchangeable potassium at close to neutral pH in the soil was sufficient to obtain a good harvest of perennial grasses of the second year of use. 4. This year, with an increase in the intensity of fertilizer systems (organomineral and mineral), a significant increase in the yield of hay of perennial grasses of 2 y.u. (from 49.1 to 67.7 c/ha) was revealed. 5. The use of mineral fertilizers at an intensive level (60 kg of a.d. of phosphorus and potassium nitrogen) led to an increase in the yield of hay pea mixture – 62.1 c/ha compared with a high-intensity level (up to 90 kg of a.d. of phosphorus and potassium nitrogen) - 61.7 c/ha.

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