METHODS OF BIOLOGIZATION OF GRAIN-GRASS CROP ROTATIONS AND THEIR INFLUENCE ON FERTILITY OF SODDY-PODZOLIC SOIL OF THE FOREST ZONE

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Abstract. On soddy-podzolic soils of the forest zone of the European part of Russia, grain-grass crop rotations are most common for the production of voluminous fodder, food and fodder grain [1,2]. In such crop rotations, the link of perennial grasses is the main factor in the reproduction of soil fertility and the production of high-quality voluminous fodder. Improvement of the grass-field link of such crop rotations based on the cultivation of new species and varieties is an urgent scientific and practical task [3,4,5].

An important way to reduce the cost of reproduction of soil fertility in grain-grass crop rotations is the maximum use of plant residues, including straw and green manure crops, which makes it possible to exclude the use of organic fertilizers on certain arable land or, if necessary, to conduct a dung-free economy [6,7,8]. Improvement of the link of perennial grasses, saturation of crop rotations with legumes, maximum use of plant residues and green manure as organic fertilizers allows to reduce the cost of reproduction of soil fertility, to produce high-quality voluminous and concentrated feed [9,10].

Keywords: forest zone, crop rotation, biologization, clover, alfalfa, cereals, productivity, feed, quality, fertility.

1. Introduction

Research on improving grain-grass crop rotations was carried out at the All-Russian Research Institute of fodder in field and lysimetric experiments with their saturation with perennial grasses from 29 to 43% by replacing vetch-oat fallow in a typical for the zone grain-grass crop rotation with clover, clover-timothy mixture for clover-alfalfa. Straw of winter cereals and green manure was used as organic fertilizers.

The experiment scheme included four crop rotations:

1) vetch-oat mixture (steam occupied), 2) winter crops, 3) spring cereals + perennial grasses (clover VIK 7 + timothy grass), 4-5) perennial grasses, 6) winter crops, 7) spring crops;

1) Early clover 2 (fallow), 2) winter crops, 3) spring cereals + perennial grasses (Early 2 clover + timothy grass), 4-5) perennial grasses, 6) winter crops, 7) spring crops + clover;

1) Early clover 2 (fallow fallow), 2) winter crops + mustard for green manure, 3) spring cereals + perennial grasses (Early 2 clover + timothy grass), 4-5) perennial grasses, 6) winter crops + mustard for green manure, 7) spring + clover;
1) Early clover 2 (fallow fallow), 2) winter crops + straw for fertilization + mustard for green manure, 3) spring cereals + perennial grasses (Early 2 clover + Vega alfalfa), 4-5) perennial grasses, 6) winter crops + straw for fertilizer + mustard for green manure, 7) spring crops + clover.

The soil is soddy-podzolic, medium loamy with a humus content of 2.1 ... 2.3%, easily hydrolyzed nitrogen 71 ... 75, phosphorus - 310 ... 320, potassium - 120-125 mg per 1000 g of soil; pH of the salt extract 5.8 ... 6.0 hydrolytic acidity - 1.7 ... 2.5 meq per 100 g of soil.

The studies were carried out on 3 backgrounds of mineral fertilizers: under winter crops (rye) and spring grain (barley) nitrogen fertilizers were applied at rates of 30 and 60 (II and III background); phosphorus and potash fertilizers for all crops with a common background – Р40К70 (1 background).

The crop rotations were deployed in space by three fields. Plot area of the second order 50 m², repetition is 3 times.

Lysimetric studies to study the balance of carbon, nitrogen, phosphorus and potassium were carried out by alternating crops in the first and fourth crop rotations.

2. Results of the research

The productivity of arable land in the control (I) and the studied crop rotations (II, III, IV) practically did not differ in the yield of dry matter and feed units and was, against the background with the introduction of nitrogen, 4.04-4.25 tons and 3.48-3.75 thousand from 1 hectare (Table 1).

Significant differences are noted in the yield of crude protein and the provision of a feed unit with it. In the second crop rotation, when replacing the vetch-oat fallow with clover fallow and cultivating early-2 clover, the yield of crude protein increases from 541-564 to 569-587 kg / ha, and its content in 1 feed unit from 144 to 149-152 g. When introduced into crop rotations of clover-alfalfa mixture, the yield of crude protein increases to 692-715 kg / ha, and the provision of feed unit with crude protein was 180 g. Harvesting feed from such plant raw materials will significantly reduce the need for high-protein supplements for cattle.

Table 1. The productivity of crop rotations depending on the species composition of crops and the background of fertilizers (on average over 10 years)

| Crop rotation number | Output from 1 hectare with the main product | dry matter, t | feed units, thousand | crude protein, kg |
|----------------------|---------------------------------------------|---------------|---------------------|------------------|
| I. Average incl.     | I   | II  | I   | II  | I   | II  | I   | II  |
| perennial herbs      | 3.89| 4.04| 4.25| 3.48| 3.75| 3.93| 519 | 541 | 564 |
| cereals              | 6.38| 6.30| 6.54| 4.48| 4.46| 4.51| 867 | 842 | 848 |
| 2. Average incl.     | 2.01| 2.34| 2.54| 2.73| 3.22| 3.49| 258 | 316 | 351 |
| perennial herbs      | 3.99| 4.05| 4.02| 3.76| 3.83| 3.85| 569 | 569 | 587 |
| cereals              | 6.51| 6.36| 6.08| 5.00| 4.76| 4.51| 959 | 926 | 908 |
| 3. On average, incl. | 2.09| 2.31| 2.48| 2.85| 3.13| 3.35| 277 | 301 | 346 |
| perennial herbs      | 3.78| 4.00| 4.03| 3.50| 3.84| 4.05| 654 | 692 | 699 |
| cereals              | 6.14| 6.20| 5.96| 4.64| 4.74| 4.70| 1170| 1199| 1144 |
| 4. Average incl.     | 2.01| 2.35| 2.61| 2.64| 3.17| 3.56| 266 | 312 | 365 |
| perennial herbs      | 3.97| 4.16| 4.07| 3.69| 3.98| 4.05| 694 | 715 | 703 |
| cereals              | 6.49| 6.58| 5.98| 5.00| 5.09| 4.74| 1249| 1243| 1151 |
| 4. Average incl.     | 2.07| 2.35| 2.64| 2.70| 3.15| 3.54| 278 | 319 | 366 |

Note: * - I, II, III - fertilizer background.

With the saturation of crop rotations with leguminous grasses, the need for nitrogen fertilizers decreased. For winter crops and cereals for clover fallow and a layer of clover-alfalfa mixture, nitrogen doses not exceeding 30 kg / ha are most effective; for the layer of clover- timofee mixture - 60 kg / ha a.i. For barley with over-sowing of grasses placed along the seam turnover, nitrogen doses should not
exceed 30 kg / ha a.i. On average, in crop rotations with 43% saturation with perennial grasses, the need for nitrogen fertilizers is 21-26 kg of ai. per 1 hectare of crop rotation area.

The influence of crop rotations on the reproduction of soil fertility is determined by the amount of organic matter and biological nitrogen entering the soil with plant residues. In the studied crop rotations, the main source of organic matter entering the soil is perennial grasses (Table 2).

After the clover-timothy mixture, the soil received 7.4-11.4, alfalfa-clover - 7.3-9.5, clover in a busy pair 4.8-5.3 t / ha of organic matter; after winter rye 3.5-4.9, barley, depending on the level of productivity from 1.5 to 3.8, vetch-oat mixture 2.1-2.4 t / ha. The application of nitrogen fertilizers (background II, III) contributed to an increase in both the total productivity and the intake of organic matter into the soil of plant residues of clover-timothy mixture, winter rye and barley.

| Crop rotation number | Perennial grasses 2 g. P. | Vico oats, clover early-2 | Winter rye + mustard | Barley at grain harvest, c / ha | Per 1 hectare of crop rotation area |
|----------------------|--------------------------|--------------------------|----------------------|-------------------------------|----------------------------------|
| I                    | I                        | 8,26                     | 2,05                 | 3,51                          | 3,15 2,10 3,03                   |
|                      | II                       | 7,64                     | 2,08                 | 4,30                          | 3,53 2,36 3,14                   |
|                      | III                      | 9,36                     | 2,35                 | 4,90                          | 3,67 3,12 3,68                   |
| II                   | I                        | 9,38                     | 4,77                 | 3,82                          | 3,15 1,52 3,55                   |
|                      | II                       | 10,38                    | 5,32                 | 4,39                          | 3,19 1,94 3,91                   |
|                      | III                      | 11,43                    | 5,10                 | 4,23                          | 3,53 2,66 4,23                   |
| III                  | I                        | 7,46                     | 5,25                 | 5,62                          | 3,06 1,52 3,60                   |
|                      | II                       | 7,35                     | 5,24                 | 6,49                          | 3,26 1,94 3,83                   |
|                      | III                      | 7,63                     | 4,94                 | 7,11                          | 3,46 2,66 4,08                   |
| IV                   | I                        | 7,95                     | 4,96                 | 7,92                          | 3,01 1,52 4,20                   |
|                      | II                       | 7,28                     | 5,23                 | 8,70                          | 3,53 1,94 4,40                   |
|                      | III                      | 9,28                     | 5,17                 | 11,20                         | 3,76 2,66 5,19                   |

Note: in crop rotation I, in a busy fallow, a vetch-oat mixture was cultivated: in crop rotations 2,3,4 - early clover-2.

On average, the studied methods of biologization make it possible to increase the flow of organic matter into the soil from 3.0-3.7 to 4.2-5.2 tons per hectare of the crop rotation area.

An important indicator of the biologization of crop rotations is the level of fixation of atmospheric nitrogen by legumes. In the studied crop rotations, the level of nitrogen fixation was in direct proportion to the saturation of the area with legumes and their varietal characteristics. In the first crop rotation with vetch-oat and clover-timothy mixture (VIC 7 clover), there were 45-48 per hectare of the crop rotation area, in the second - with the replacement of vetch-oat fallow with clover and the introduction of Early 2 clover into the grass mixture - 80-83, in the third and fourth crop rotations, 100-109 kg of total symbiotic nitrogen. After clover with alfalfa, nitrogen entered the soil 140-147, clover VIK 7 with timothy - 143, early 2 clover with timothy - 153 kg / ha. In the occupied fallow after the Early 2 clover, 105-130 kg / ha of nitrogen entered the soil with plant residues, which is 3.7-4.5 times more than in the vetch-oat mixture.

For the formation of the total biomass of perennial grasses, a large amount of potassium was consumed: mixtures of early 2 clover with alfalfa 409-430, early 2 clover with timothy - 523-533, VIK 7 clover with timothy 458-513 kg / ha. At the same time, 55-58, 85-103 and 63-77 kg / ha were supplied to the soil with plant residues, respectively. When using Early 2 clover in a single-cut mode in a busy fallow, the consumption of potassium was 204-293, of which 59-83 kg / ha entered the soil with plant residues.
The consumption of phosphorus (P₂O₅) for the formation of biomass of perennial grasses is 78-88% replenished with mineral fertilizers, and its deficit did not exceed 6-23 kg / ha.

In accordance with the calculated data, perennial grasses have a positive balance of carbon and nitrogen, and a negative balance of potassium (Table 3).

**Table 3.** The balance of carbon, nitrogen and potassium in the cultivation of perennial grasses in crop rotations (kg / ha)

| Crop rotation, N rate for cover crops, kg / ha | Grassland link | Busy couple |
|-----------------------------------------------|---------------|-------------|
|                  | species, variety | carbon, C | N   | K₂O | species, variety | carbon, C | N   | K₂O |
| I 0              | Clover          | +1075     | +7  | -266| vico            | -210      | -104| -48 |
| 30               | VIC 7 + timothy | +1007     | +7  | -215| oatmeal mixture | -132      | -96 | -57 |
| 60               | Clover          | +1410     | +27 | -234|                | -20       | -51 | -43 |
| II 0             | Clover          | +1288     | +16 | -328| clover early-2 | +787      | +47 | -91 |
| 30               | Early-2 + timothy | +1284 | +8  | -265|                | +1072     | +66 | -69 |
| 60               | Clover          | +1517     | +18 | -300|                | +970      | +74 | -41 |
| III 0            | Clover          | +1122     | +27 | -202| clover early-2 | +1055     | +67 | -91 |
| 30               | Early-2 + timothy | +1100 | +25 | -239|                | +854      | +69 | -79 |
| 60               | Clover          | +1162     | +28 | -250|                | +754      | +42 | -103|
| IV 0             | Clover          | +1172     | +26 | -238| clover early-2 | +796      | +45 | -98 |
| 30               | Early-2 + alfalfa | +1179 | +34 | -188|                | +963      | +59 | -117|
| 60               | Clover          | +1497     | +55 | -163|                | +797      | +45 | -111|

Under the mixtures of perennial grasses, the input of carbon into the soil is higher than its mineralization by 1007-1517, under the clover Early 2 in a busy fallow by 787-1072 kg / ha. The excess of nitrogen input into the soil over the removal after the legume-grass mixture averaged 14 kg / ha at the balance intensity of 105%, after the legume mixture - 33 kg / ha and 108%, respectively. In the occupied fallow after the Early 2 clover, the excess under the removal was 57 kg / ha. After the vetch-oat mixture, the balance of carbon, nitrogen and potassium was negative.

The second group of crops with positive environment-forming properties are winter cereals. In terms of the amount of plant residues entering the soil, winter crops are slightly inferior to perennial grasses. When plowing straw and white mustard for green manure, an additional 3.9-4.4 t / ha of organic matter was added to the soil.

On average, the effect of crop rotations on the balance of carbon, nitrogen and ash elements, agrochemical parameters of the soil was determined by the specific weight of perennial grasses in the structure of sown areas, the use of straw and green manure for fertilization. With the saturation of crop rotations with perennial grasses up to 43%, the input of organic matter into the soil increased from 3.03-3.68 (crop rotation I) to 3.55-4.23 (crop rotation II), and with additional plowing of straw and green manure (crop rotation III, IV) - 4.20-5.19 t / ha dry matter. The calculated carbon balance in all crop rotations was positive.

The nitrogen regime for the rotation of crop rotations was determined by the proportion of perennial grasses and the level of fertilization. In crop rotation II, a positive balance was noted with an average rate of nitrogen fertilizers - 34 kg / ha of the island; in crop rotations III and IV when plowing straw and green manure - with an average nitrogen rate of 17 kg / ha.

A significant potassium deficiency was noted in all crop rotations. Its removal with the harvest was provided with fertilizers by 60-65%. When plowing straw, the potassium deficiency decreased slightly. The phosphorus balance in the crop rotations was positive. The intake of P₂O₅ with fertilizer (P₆₀) exceeded its removal with the harvest by 3-8 kg / ha.

Agrochemical indicators of soil fertility at the end of the first rotation of crop rotations differed slightly compared to the initial state. The positive influence of biological methods on the content of
reproducible humus or labile organic substances in the soil (LOS) has been noted. At the beginning of the experiment, the LOS content was 9.2 t / ha; after perennial grasses, their number increased to 10-11 t / ha; after winter rye it changed insignificantly, and after barley it decreased by 2.6-4.3 t / ha. More optimal conditions for the formation of LOSs were noted in the crop rotation with 43% saturation with legumes, plowing straw and green manure into the soil.

3. Conclusion
Thus, the introduction of grain-grass crop rotations saturated with leguminous grasses of more productive varieties allows, due to biological factors, to significantly increase the supply of forage with protein, reduce the cost of their production, optimize the carbon and nitrogen regime of the soil, and reduce the need for nitrogen fertilizers. In such crop rotations, no more than 26 kg / ha of a.i. is needed per 1 hectare of area. nitrogen. Phosphate fertilizers should be applied taking into account the content of P₂O₅ in the soil or based on its removal by the crop. The need for potash fertilizers is high: the doses of potash fertilizers for perennial grasses should be on average about 120, for cereals - 60-80 centners / ha. For a more accelerated replenishment of organic matter in such crop rotations, straw of winter crops and white mustard for green manure should be used as organic fertilizers.

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