Comparative evaluation of productivity of ryegrass and ryegrass-goatling grass stands affected by different mineral and organomineral nutrition

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Abstract. Production volumes must be increased not by any means, but only by those of them that are economically sound and justify the labor of present-day agricultural workers and funds spent on solution of its problems. The number of such priorities undoubtedly includes realization of the complex program of developing biotechnologies, approved by the President of the Russian Federation, V.V. Putin, on April 24, 2012. It is aimed at the reduction of expenditures on the production of competitive, environmentally safe foodstuff based on widespread use of modern fertilizing and stimulating compositions, organic and mineral nutrient solutions and biological preparations. In this connection, the questions of foliar dressing, discussed in this work, using various nutrient solutions, containing highly digestible amino acids and chelate forms of microfertilizers of poorly explored in Middle Volga region ryegrass agrocoenoses, are not only relevant, but are also significant from the theoretical and practical viewpoints.

1. Introduction
The problems of application of fertilizing and stimulating compositions in presowing cultivation of seeds of agricultural crops were studied in the research of such well-known foreign scholars as U Yermiyahu, M Halpern (2015), A K Srivastava, P Suprasanna (2016), J R Reeve, L A Hoagland (2016).

In particular, I M Serzhanov (2013), R I Safin (2013), R M Nizamov (2019) made a great contribution to the theory of application of biologically active substances in the agroindustrial sector of Volga Federal District.

They in unison state that biologically active substances increase the accumulation of the biomass, change the ratio between generative and vegetative shoots, increase the quality of the manufactured products, increase stress tolerance of crops to unfavorable conditions of the environment [1-3].

However, in the course of literature study and conducting patent research, we have not found publications in Russian and foreign editions of research results, devoted to the foliar dressing of ryegrass and ryegrass-goatling grass stands.

The purpose is to develop and implement practical methods for increasing the production of energy-rich, high-protein, sugar-protein-balanced fodder based on the expansion of the acreage of ryegrass and ryegrass-goatling grass stands and the optimization of their nutrition status.

To accomplish this purpose, the following tasks were planned:
1. to conduct a comparative evaluation of yields of ryegrass and ryegrass-goatling grass stands, depending on the status of mineral and organo-mineral nutrition;
2. to study the quality of fodder and the ratio of nutrients;
3. to calculate the economic efficiency of the calculated norms of mineral fertilizers and complex nutrient solutions on ryegrass agro-ecosystems.

2. Research methods

Field experiments were carried out in 2014-2017 on the experimental field of the Agronomic Faculty of Kazan State Agrarian University with following GPS coordinates: N 55°39'51"; E 49°11'33" (typical forest-steppe zone of the Middle Volga region). It is on gray forest soils with initial humus content of 3.91% according to Tyurin, labile phosphorus of 152 and exchangeable potassium of 168 mg/kg of soil according to Kirsanov. The salt pH extract was weakly acid - 5.9. The soil density was 1.2 g/cm³, the lowest moisture content was 28%.

There were 4 replications of the experiment, the total area of the plot is 36 (3.6x10) m², the accounting area is 21 m². The grass stands: two green mass, were cut.

The experiment was on May 26, 2013 with pure sowing.

Phenological observations, recording of grass stands density, plant height, yield, etc. were carried out according to the method of Williams Fodder Research Institute [4].

In variance analysis of research results, the scientific works of B.A. Dospekhova were used [5].

The economic efficiency of the studied experience variants was calculated in comparable prices of oat grain (600 rubles per 100 feed units) for prices of 2018 [6, 7].

The study objects were single-species crops of multicut ryegrass (Lolium multiflorum, variety Leningradsky 809) and its mixed crops with oriental goatling (Galega orientalis, variety Gale). The ratio of ryegrass of 60% and oriental goatling of 40% was established taking into account the mass of 1000 seeds in a total seeding rate of 30 kg/ha.

The dose of mineral fertilizers was determined by the calculation and balance method for a planned yield of 30 t/ha of green mass.

For foliar nutrition of plants we used Izagri NPK (produced by ‘Izagri’ CJSC) permitted for use in the Russian Federation with a nitrogen content of 41.1%, phosphorus - 27.7%, potassium -15.2%, a complex of micronutrients in an easily-accessible form and Biocomposite-Correct (produced by ‘Schelkovo Agrokhim’ JSC), enriched with readily available amino acids, growth stimulants and trace elements. The consumption rate was set on the basis of manufacturers' recommendations - 6 l/ha + 300 l/ha H₂O proportionally in two steps: in spring and after cut, on the same day of the soil dressing with nitrogen-phosphorus-potassium fertilizers.

Weather and climatic conditions during the years of the research were typical for this zone: arid (2014, 2015) and fairly wet (2017).

3. Results and discussion

After early-spring feeding of ryegrass agro-ecosystems with mineral fertilizers and nutrient solutions for the 10th -12th day, the plant color changed to bright green color. The tillering (1046 pieces/m²) of meadow ryegrass and branching of oriental goatling (1205 pieces/m²) increased. Plant growth rates accelerated in height (74 cm before the first cutting) versus 765; 801; 52, respectively, using the unfertilized variants of the experience.

The formation of dense tall grass stand reduces the part of unproductive forbs from 18.7% in 2014 to 3.6% before the second cut in 2017 of ryegrass-goatling grass stands.

As a result, the green mass yield of sowing single-species ryegrass in the sum of 2 cuttings per the variant with the introduction of N₈₈P₃₅K₁₃ proportionally in 2 doses (in spring and after the 1st cutting by N₃₈,P₁₇,K₂₁,₅) was 28.8 t/ha (96% of planned one) accompanied by an increase in dry mass to the control of 49.8% (Table 1).

In addition to the fodder status, the selection of grass mixtures plays a major role in the productivity of ryegrass farm ecosystems. For example, to obtain 7.22 t/ha of dry mass of ray-grass stands, it was
necessary to apply 166 kg/ha of NPK’s application rate. For ryegrass-goatling meadows the estimated rate of mineral fertilizers is 61 kg/ha (105 kg/ha less) provided by 7.46 t/ha of dry weight.

**Table 1.** Effect of mineral fertilizers and complex nutrients solutions on yield of ryegrass agro-ecosystems (2014–2017)

| Factor A (types of grass stands) | Factor B (nutrition status) | Yield in the amount of 2 cutting, t/ha | Dry mass gain |
|----------------------------------|-----------------------------|----------------------------------------|---------------|
| Multicut ryegrass (control)      | Control (without fertilizer) | 18.4                                   | 4.82          |
|                                  | N<sub>88</sub>P<sub>35</sub>K<sub>43</sub> (for 30 t/ha) | 28.8                                   | 7.22          |
|                                  | Izagri NPK - 6 l/ha         | 20.3                                   | 5.24          |
|                                  | Biocomposite Correct - 6 l/ha | 22.1                                   | 5.57          |
| Ryegrass 60% + Oriental goatling 40% | Control (without fertilizer) | 20.0                                   | 5.20          |
|                                  | N<sub>88</sub>P<sub>35</sub>K<sub>43</sub> (for 30 t/ha) | 28.9                                   | 7.46          |
|                                  | Izagri NPK - 6 l/ha         | 23.1                                   | 5.98          |
|                                  | Biocomposite Correct - 6 l/ha | 21.6                                   | 5.62          |
| HCP<sub>95</sub> A               | 0.21                        | 0.14                                   |
| HCP<sub>95</sub> B               | 0.28                        | 0.19                                   |
| HCP<sub>95</sub> AB              | 0.32                        | 0.21                                   |

Responsiveness of single-and multi-species crops of multicut ryegrass to double foliar feeding with concentrated nutrient solutions differed radically from each other. Biocomposite-Correct proved to be the most effective on pure sowing of multicut ryegrass (an increase for 2 cuttings in average over 4 years amounted to 0.75 t/ha of dry weight, which is 15.6% higher than the control), and on mixed sowing with oriental goatling Izagri NPK (5.98 t/ha of dry mass versus 5.20 t/ha in the unfertilized variant) provided the highest yields.

It is well known that perennial grasses are different from other fodder crops by their high stress resistance, especially drought tolerance and resistance to dry winds. Nevertheless, soil and leaf top-dressings give an additional impetus to the stabilization of the productivity of research objects. Concerning the pure sowing without fertilization, the yield amplitude ranged from 17.5 t/ha of green mass in arid 2016 to 20.1 t/ha in a favorable 2017 (difference of 2.6 t/ha). In the same years, the variation in the green mass yield over the research years on the variant with the introduction of NPK decreased to 1.7 t/ha, which is also typical of variants with foliar feeding of ryegrass-goatling stands.

Grassland scientists and farmers have always been interested in the possibility of eliminating the summer depression of perennial aftergrasses so that the plant biomass for forage can be supplied evenly throughout the growing season. To a great extent, this problem can be solved in two ways:

- selection of grass mixtures containing such leguminous perennials with a high ability of regrowth after the 1st cut as an oriental goatling;
- optimization of mineral and organo-mineral nutrition, from the point of view of not only economic feasibility, but also the harvest distribution among the cuttings (Figure 1).

In the variant with application of estimated norms of mineral fertilizers (N<sub>88</sub>P<sub>35</sub>K<sub>43</sub>) in proportion to two doses, the planned yield of 30 t/ha of green mass of ryegrass stands for the first cutting is 54.9% of the harvest (15.8 t/ha of green mass), and the second cut is 45.1% (13.0 t/ha).
Figure 1. Impact of nutrition status on the distribution of total yield of green mass of ryegrass agro-ecosystems as per cuttings: (a) pure sowing of multicut ryegrass; (b) ryegrass 60% + oriental goatling 40%.

On mixed ryegrass sowing with oriental goatling, the biomass distribution on the variant with introduction of N<sub>88</sub>P<sub>35</sub>K<sub>43</sub> (by 105 kg/ha less) occurs more evenly (1st cut 54.0%, second - 46%).

Very satisfactory results on distribution of green mass of the studied grass stands were obtained on variants with foliar feeding of plants. At the same time, for pure sowing of multicut ryegrass was the Biocomposite Correct in dosage 3 l/ha + 300 l/ha H<sub>2</sub>O in the spring and after the 1<sup>st</sup> cutting was 56.1% (12.4 t/ha) and 43.9% (9.7 t/ha), and for polycrop sowing - Izagri NPK. The advantage of Izagri NPK was apparently due to the fact that it contained water-soluble molybdenum, which stimulates the nitrogen-fixing ability of nodule bacteria [8-10].

Thus, the use of calculated norms of mineral fertilizers and modern complex nutrient solutions not only increases the yield of ryegrass agro-ecosystems by 15-50%, but also contributes to a more uniform distribution of the total yield among the cuttings.

Chemical analyses of plant samples showed strong arguments in favor of mixed sowing of ryegrass with oriental goatling on both non-fertilized and fertilized variants of the experiment.

In absolutely dry weight of ryegrass-goating agro-ecosystems, the content of digestible protein ranged from 11.3 in the case of control to 13.9% with application of N<sub>88</sub>P<sub>35</sub>K<sub>43</sub> against 9.0-11.0% on pure sowing of this crop. The highest gross yield of fodder units per area unit (5670) was also provided by mixed ryegrass sowing with oriental goatling of 176 g / kg of digestible protein (table 2).

In conclusion, it is necessary to mention very high saturation of fodder units with digestible protein in experiment variants with foliar feeding including organo-mineral fertilizers as well (175-177 mg/kg, which is 55-57 mg/kg higher than the standard indicators).

Unfortunately, such high saturation of fodder units with digestible protein causes a decrease in the amount of sugars and, most importantly, an imbalance of the sugar-protein ratio in the diet of animals (Table 3).
### Table 2. Gross collections of digestible protein and fodder units depending on the food regime of gray forest soils of Middle Volga region (2014-2017)

| Factor A (types of grass stands) | Factor B (nutrition status) | Digestible Protein | Fodder units |
|---------------------------------|-----------------------------|--------------------|--------------|
|                                 |                             | % in abs. dry mass | gross collecti on, kg/ha | % in abs. dry mass | gross collecti on, kg/ha | saturation with digestible protein, g/kg |
| Multicut ryegrass (control)     | Control (without fertilizer) | 9.0                | 434           | 0.53          | 2555                   | 170                              |
|                                 | N88P35K43 (for 30 t/ha)     | 11.0               | 794           | 0.64          | 4621                   | 172                              |
|                                 | Izagri NPK - 6 l/ha         | 9.9                | 519           | 0.56          | 2934                   | 177                              |
|                                 | Biocomposite Correct - 6 l/ha | 10.4             | 579           | 0.58          | 3231                   | 179                              |
|                                 | Control (without fertilizer) | 11.3               | 585           | 0.68          | 3536                   | 165                              |
|                                 | N88P35K43 (for 30 t/ha)     | 13.4               | 1000          | 0.76          | 5670                   | 176                              |
| Ryegrass 60% + Oriental goatling 40% | Izagri NPK - 6 l/ha         | 12.6               | 753           | 0.71          | 4246                   | 177                              |
|                                 | Biocomposite Correct - 6 l/ha | 12.1             | 679           | 0.69          | 3874                   | 175                              |

### Table 3. Content, gross collections, sums of sugar and sugar-protein ratio in ryegrass and ryegrass-goatling fodders

| Factor A (types of grass stands) | Factor B (nutrition status) | Contents of sugars sums in abs. dry mass, % | Gross collection of sugars sums, kg/ha | Sugar-protein ratio |
|---------------------------------|-----------------------------|---------------------------------------------|---------------------------------------|--------------------|
| Multicut ryegrass (control)     | Control (without fertilizer) | 11.5                                        | 554                                   | 1.28:1             |
|                                 | N88P35K43 (for 30 t/ha)     | 7.8                                         | 563                                   | 0.71:1             |
|                                 | Izagri NPK - 6 l/ha         | 11.4                                        | 597                                   | 1.15:1             |
|                                 | Biocomposite Correct - 6 l/ha | 11.6                                     | 646                                   | 1.11:1             |
|                                 | Control (without fertilizer) | 9.9                                         | 515                                   | 0.88:1             |
|                                 | N88P35K43 (for 30 t/ha)     | 7.2                                         | 537                                   | 0.54:1             |
|                                 | Izagri NPK - 6 l/ha         | 9.9                                         | 592                                   | 0.79:1             |
| Ryegrass 60% + Oriental goatling 40% | Biocomposite Correct - 6 l/ha | 11.1                                     | 557                                   | 0.82:1             |

In the absolutely dry mass of ryegrass-goatling grass stands, the content of sugars sums is reduced to 7.2% when N44P12K6 is added. In this regard, the ratio of sugars sums to the digestible protein is only 0.54:1, which is 46% lower than the standard figure. Such sharp drop in sugars sums in biomass of ryegrass-goatling stands is avoided by replacing mineral fertilizers with complex concentrated nutrient solutions (Izagri NPK 0.79:1, Biocomposite Correct 0.82:1, which is within the allowable value).

The final criterion for assessing the impact of various types of fertilizers is the economic indicators of the production of ryegrass and ryegrass-goatling fodders (table 4).

Before proceeding with the analysis of the data in table 4, the high profitability of the production of ryegrass fodders should be noted: 16.8% without the use of mineral fertilizers and 35.8% with N88P35K43 in nutrition status.
Table 4. Economic efficiency of mineral and liquid complex fertilizers on pure sowing and polyspecies sowings of multicut ryegrass

| Factor A (types of grass stands) | Factor B (nutrition status) | The cost of gross products, thousand rubles/ha | Total costs, thousand rubles/ha | Conditionally net income, thousand rubles/ha | Profitability, % | The cost of 100 kg feed. units, rub. |
|----------------------------------|----------------------------|----------------------------------------------|--------------------------------|---------------------------------------------|-----------------|---------------------------------|
| Multicut ryegrass (control)      | Control (without fertilizer) | 15.3                                         | 13.1                          | 2.2                                         | 16.8            | 513                             |
|                                  | N88P35K43 (for 30 t/ha)      | 27.7                                         | 20.4                          | 7.3                                         | 35.8            | 441                             |
|                                  | Izagri NPK - 6 t/ha          | 17.6                                         | 14.6                          | 3.0                                         | 20.5            | 498                             |
|                                  | Biocomposite Correct - 6 t/ha | 19.4                                         | 15.8                          | 3.6                                         | 22.8            | 489                             |
| Ryegrass 60% + Oriental goatling | Control (without fertilizer) | 21.2                                         | 17.7                          | 3.5                                         | 19.8            | 501                             |
| 40%                              | N88P35K43 (for 30 t/ha)      | 34.0                                         | 22.4                          | 11.6                                        | 51.8            | 395                             |
|                                  | Izagri NPK - 6 t/ha          | 25.5                                         | 20.0                          | 5.5                                         | 27.5            | 471                             |
|                                  | Biocomposite Correct - 6 t/ha | 23.3                                         | 19.1                          | 4.2                                         | 22.0            | 493                             |

When sowing the multicut ryegrass mixed with oriental goatling on unfertilized version of soil in the experiment, a conditionally net income rises to 3.6 thousand rubles/ha, which is 1.4 thousand rubles/ha higher than pure sowing.

100 fodder units with the lowest cost (395 rubles) of ryegrass-goatling sowings were produced in the experiment of N88P35K43 application.

From an economic point of view, Biocomposite Correct in pure sowing was found to be 22.8% profitable for fodder production and gross net income of 3.6 thousand rubles per hectare, which is 6% and 1.4 thousand/ha rubles higher than the non-fertilized variant. Izagri NPK showed the best results on ryegrass sowings mixed with oriental goatling: the value of gross output was 25.5 thousand rubles/ha, conditional net income - 5.5 thousand rubles/ha, profitability – 27.5%. With a conditional sales price of 600 rubles per 100 feed units, 129 rubles remain in the farm.

4. Conclusion

Therefore, in order to obtain 5670 fodder units with a profitability of 51.8% on the gray forest soils of Middle Volga region of the Russian Federation, the multicut ryegrass must be cultivated in a mixture with the oriental goatling with the calculated mineral nutrition status N35P12K8. In those farms where it is not possible to save money, it is recommended to replace the mineral fertilizers for pure sowing of ryegrass with Biocomposite-Correct, and with Izagri NPK for mixed sowings with oriental goatling at a rate of 6 t/ha (by 3 t/ha + 300 l/ha H2O at the beginning of the growth of perennial grasses and after the first cut).

The recommended complex nutrient solutions provide an even distribution of total yield by cuttings (55.4 and 44.6%), increase the saturation of fodder units with digestible protein up to 175-177 g/kg (55-57 g/kg higher than the standard value) and stabilize a sugars-protein ratio in the cattle rations to 0.8:1.

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