Optimization of mineral nutrition for perennial ryegrass seed production

Mēslošanas optimizācija ganību airenēs sēkladzēšanā

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Abstract. The efficiency of N fertilizer used in perennial grass seed production in Latvia may affect the nitrogen rate, grass species, and soil type. Grass seed production is a very important factor for farmer’s income in Latvia. The objective of this research was to obtain productivity results for perennial ryegrass (Lolium perenne L.) at different rates of mineral nutrition. Field experiments were carried out on sod-podzolic sandy loam soil. The following mineral fertilizer rates were used: N and P₂O₅, each 0, 30, 60, 90, 120, K₂O - 0, 40, 80, 120, 160 kg ha⁻¹. Productivity of biomass and seeds was dependent on the following variables: genetic characteristics of particular cultivars, mineral fertilizer rates, and meteorological conditions of the growing period. This research examines the effects of varying mineral fertilizer rates on dry matter and seed yields by using perennial ryegrass cultivar ‘Spidola’ and relies on the local weather conditions. The average biomass yield was 2.21-6.07 t ha⁻¹ (on dry matter basis), while the average seed yields were 255-672 and 136-390 kg ha⁻¹ in the 1st and 2nd year stand, respectively.

Key words: fertilizer use, perennial ryegrass seed production, yield quality.

Introduction

Grass species often used for forage production as hay or pasture systems include timothy (Phleum pratensis L.), perennial ryegrass (Lolium perenne L.), meadow fescue (Festuca pratensis Huds.), orchardgrass (Dactylis glomerata L.) and Kentucky bluegrass (Poa pratensis L.). High yields of perennial ryegrass seed production in Latvia depend on abundant plant-available N.

Perennial ryegrass species has great seed production potential. However, it is very difficult to use, practically due to the many biotic and abiotic factors forming interaction within the system plant–environment–fertilizers. In order to obtain a good perennial grass seed yield, it is important to have these following preconditions: high enough temperature, rain during the flowering stage, seed maturation, as well as the use of proper cultivars with high seed yielding capacity and the application of adequate fertilization.

Perennial ryegrass is a major component in different seed mixtures that are used for grassland management and forage production. This grass species plays an important role in grassland productivity and forage quality. Agro-climatic conditions have a very significant role in grass seed production and optimization of mineral nutrition for perennial ryegrass (Havstad, 1998).

Perennial ryegrass cultivars ‘Spidola’ were developed at the Skrīveri Research Center of the Latvia University of Agriculture (LLU). It is a tetraploid cultivar developed by doubling the chromosomal count of perennial ryegrass ‘Priekulu 59’. The ‘Spidola’ attributes are of higher productivity than those of ‘Priekulu 2’, have better winter hardiness, good disease resistance, and provide good feedlot. Also ‘Spidola’ cultivar shows a preference for certain growing conditions, is better suited for mineral soils, prefers loamy or loamy sand soils, and does quite well on clay soils, but is somewhat less responsive on light soils. Peat soils are not suitable for growing of this cultivar of perennial ryegrasses and do not have the ability to tolerate excessive moisture for the long growing season period. It is suitable for inclusion in seed mixtures planned for establishment of permanent pastures and is a late maturing pasture grass, good for late grazing.

Presently there is no research in Latvia on which it is possible to make good fertilizer use recommendations and provide advisory support to farmers involved in the perennial ryegrass seed production. The objective of this research was to obtain productivity results for perennial ryegrass at different rates of mineral nutrition.

Materials and methods

Field experiments were carried out on sod-podzolic sandy loam soil (Luvic Phaeozem, WRB, 1998), pHKCl 6.5, plant available P₂O₅ 110 and K₂O 204 mg kg⁻¹ (Egner-Riehm), soil organic carbon 12.2 g kg⁻¹ (Tyurin’s method). Meteorological conditions of the growing season were characterized by increased rainfall (280-370 mm) during the seed production period (June-August) in both years (2000 and 2001). Randomized complete block design with four replicates was used. The plot size was 16 m². Five fertilizer rates were applied in both years. Perennial ryegrass (12 kg ha⁻¹) was planted using Nordsten seed drill in May 1999 and 2000 after field preparation. The following mineral fertilizer rates were used: N and P₂O₅, each of them 0,
30, 60, 90, and 120 kg ha⁻¹, K₂O – 0, 40, 80, 120, and 160 kg ha⁻¹ (ammonium nitrate, single superphosphate and potassium chloride). Weed control was performed using MCPA 1.1 ha⁻¹ in mixture with 8-10 g ha⁻¹ of Granstar. Seed yield response of cool-season grasses to spring-applied N is usually limited because of lodging (Young, et al., 1999). Lodging of perennial ryegrass plant is a widespread problem. Crop lodging reduces seed yield and interferes with seed harvest (Young, et al., 1996).

Lodging of the perennial ryegrass stand was evaluated during the growing season using a scale from 1 to 10 (1 = the stand is completely lodged, 10 = lodging is not observable). The biomass, dry matter content, seed yield as well as its chemical composition were determined. Seed yield was recorded from the 1st year and 2nd year sward use. Analysis of yield components and other parameters were also recorded. The Kjeldal procedure was used for total nitrogen and crude protein determination as described by Brenner and Breitenbeck (1983). Dry matter digestibility in vitro was obtained. Analysis of variance (ANOVA) was conducted using the GLM procedure of SAS (SAS Inst., 1990) at P=0.005 to test the effects of year, location, N treatment, and all interactions.

Results and discussion
Fertilizer application showed positive effects on the increase of 1st cut perennial ryegrass biomass. The dry matter yield doubled and even more, compared with unfertilized plots (Fig. 1). Significant increase of seed yield was also obtained in both cases using 1st year and 2nd year sward use (Fig. 2). The clear tendency in the observed yield (both biomass and seed) was more dependent on N fertilizer treatments than on phosphorus and potassium. Even relatively small fertilizer rates provided a significant yield increase, e.g. dry matter (DM) yield of 4.00 t ha⁻¹ was reached when only N₃P₅O₁₀K₂O was applied but it is 1.79 times or 81% higher compared with unfertilized treatments. Further increase of nitrogen rates up to the maximum used in the experiment (120 kg ha⁻¹) produced a positive effect. Perennial ryegrass ‘Spidola’ responded to N fertilizer application; the DM yield for 1st cut increased by 1.85 t ha⁻¹ or 60% as applied N rates increased from 30 to 90 kg ha⁻¹. Comparison of treatments with constant nitrogen applications but different PK fertilizer rates demonstrated only a slight effect.

The maximum dry matter yield (6.07 t ha⁻¹) was obtained using the highest (in this experiment) fertilizer rates: N₁₂₀P₁₂₀K₂₀₀ or all together 400 kg ha⁻¹ plant nutrients. Evaluating the plant nutrient use efficiency by a single parameter – the yield increase per 1 kg of nutrients applied – the range of tested treatments might be as follows: N₃P₅O₁₀K₂O = 17.9, N₆₀P₅O₁₀K₁₂₀ = 10.0, N₆₀P₅O₁₀K₀ = 14.2, N₁₂₀P₅O₁₀K₁₂₀ = 22.8, N₁₂₀P₅O₁₀K₂₀₀ = 12.4, and N₁₂₀P₅O₁₀K₂₀₀ = 9.7 kg. Medium nitrogen and small PK rates (N₆₀P₅O₁₀K₂₀₀) provided the maximal perennial ryegrass dry matter increase per 1 kg of nutrients applied ~ 22.8 kg.

Seed harvested early in the season produced a low weight and low germination rate. Such seed was not suitable for longer storage (Slapetsys, 2001). Our finding agreed with the research of Loeppky et al. (1999) that

![Fig. 1. The dry matter yield (DM) of 1st cut perennial ryegrass, t ha⁻¹](image)

* – Here and afterwards designations P₅O₁₀ and similar mean 30 and 40 kg ha⁻¹ of P₂O₅ and K₂O, respectively.
Fig. 2. The seed yield of 1st and 2nd cut perennial ryegrass, kg ha⁻¹

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Content in dry matter, g kg⁻¹</th>
<th>Crude protein yield, t ha⁻¹</th>
<th>Digestibility, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₀P₀K₀</td>
<td>91.1</td>
<td>257.0</td>
<td>0.20</td>
</tr>
<tr>
<td>N₂₀P₂₀K₂₀</td>
<td>92.8</td>
<td>249.8</td>
<td>0.37</td>
</tr>
<tr>
<td>N₄₀P₄₀K₄₀</td>
<td>95.8</td>
<td>248.5</td>
<td>0.44</td>
</tr>
<tr>
<td>N₆₀P₆₀K₆₀</td>
<td>103.0</td>
<td>242.9</td>
<td>0.52</td>
</tr>
<tr>
<td>N₈₀P₈₀K₈₀</td>
<td>111.4</td>
<td>254.8</td>
<td>0.65</td>
</tr>
<tr>
<td>N₁₀₀P₁₀₀K₁₀₀</td>
<td>114.6</td>
<td>253.3</td>
<td>0.68</td>
</tr>
<tr>
<td>N₁₂₀P₁₂₀K₁₂₀</td>
<td>133.4</td>
<td>254.0</td>
<td>0.81</td>
</tr>
</tbody>
</table>

nitrogen significantly increased forage seed yields of all species except alfalfa, while phosphorus increased the yield of forage seed for all crops except intermediate wheatgrass. The yield response to N and P fertilizers was affected by available soil N and P.

In the 1st production year, the produced seed yield was 522 kg ha⁻¹ or by 267 kg ha⁻¹ more in treatment N₂₀P₂₀K₂₀ compared with unfertilized plot (Fig. 2). The N fertilizer rate increase from 30 to 90 kg ha⁻¹ resulted in increased seed yields by 108 kg ha⁻¹ or 21%, however, higher rates of P and K gave a seed yield of 187 kg ha⁻¹ or by 54 kg ha⁻¹ more in treatment N₄₀P₄₀K₄₀ compared with treatment receiving no fertilizer. The seed yield increase by 144 kg ha⁻¹ or 77% was reached applying 90 kg ha⁻¹ of N. Increased P and K fertilizer rates resulted in a 5 kg ha⁻¹ or 3% seed yield increase.

Increased NPK rates resulted in the following increase of seed yields: 105-164% in the 1st and 41-201% in the 2nd production year. Fertilization proved to be significant in all cases.

The crude protein (CP) content in grasses is one of the quality indices if the grass is to be used as forage. The CP content in the 1st cut grass ranged from 91.1 g kg⁻¹ in N₀P₀K₀ treatment up to 133.4 g kg⁻¹ in N₁₂₀P₁₂₀K₁₂₀ treatment (Table 1).

The crude fiber (CF) content was 257.0 g kg⁻¹ and digestibility was 65.2% in treatment N₀P₀K₀ (Table 1). The CP content increased by 1-5%, but digestibility increased by 1-4% in treatments with NPK applied (except at treatment N₄₀P₄₀K₄₀ where digestibility reduced by 2.4%) compared with unfertilized plot.

The 1000 seed mass ranging from 2.8 to 2.9 g and higher by 0.1 g or 4.0% were obtained in the following fertilizer treatments: N₀P₀K₀, N₁₀₀P₁₀₀K₁₀₀ and N₁₂₀P₁₂₀K₁₂₀ (Table 2).

The number of productive stems is one of the yield structure indices and in the experiment in unfertilized treatment constituted 869 per m². In plots treated with NPK fertilizer, the amount of productive stems ranged from 1121 to 1298 per m² or 25-43% more compared with unfertilized plot.

Lodging resistance is another important parameter for seed production. If the stand is completely free from lodging, usually the grass density is sparse and as a result grass is low productive. A denser stand and higher fertilizer (especially nitrogen) rates produce more
Effect of mineral fertilizer rates of 1st year perennial ryegrass on the seed yield and its formative elements

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Seed yield, kg ha⁻¹</th>
<th>Productive stems, number per m²</th>
<th>Lodging resistance, scores</th>
<th>1000 seed mass, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0P0K0</td>
<td>255</td>
<td>869</td>
<td>8.9</td>
<td>2.8</td>
</tr>
<tr>
<td>N0P30K40</td>
<td>522</td>
<td>1121</td>
<td>7.0</td>
<td>2.8</td>
</tr>
<tr>
<td>N0P30K120</td>
<td>539</td>
<td>1243</td>
<td>6.0</td>
<td>2.9</td>
</tr>
<tr>
<td>N0P60K40</td>
<td>592</td>
<td>1298</td>
<td>4.5</td>
<td>2.8</td>
</tr>
<tr>
<td>N0P90K40</td>
<td>620</td>
<td>1165</td>
<td>2.9</td>
<td>2.8</td>
</tr>
<tr>
<td>N0P90K120</td>
<td>653</td>
<td>1233</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>N120P120K160</td>
<td>672</td>
<td>1234</td>
<td>2.2</td>
<td>2.9</td>
</tr>
<tr>
<td>LSD₀.₀⁵</td>
<td>74.05</td>
<td>220.28</td>
<td>1.41</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Conclusion
The maximum dry matter yield can be obtained using the highest fertilizer rates – N₁₂₀ P₁₂₀ K₁₆₀. The maximum gain in seed yield can be obtained using medium N and small PK rates (N₉₀ P₆₀ K₄₀). Additional increases in PK rates produce a minimal dry matter yield gain.

Using the lowest fertilization rate more than doubled the seed yield compared with unfertilized plots. Subsequent fertilizer rate increases locally for the first year produced a nearly linear small increase in seed yields. Second year seed yields increased from a little more than a third of the 1st year yield for two lower NPK rates to about one half of the 1st year yield. The second year yields were higher compared with the 1st year’s use of higher NPK rates. Optimal productive density in perennial ryegrass seed plot is 1100-1298 productive ears per hectare. The fields of grass seed were comparatively more productive with estimated lodging resistance between 6 and 7. Optimization of mineral nutrition in perennial ryegrass seed production fields has a positive effect on yield structure and seed quality parameters.

References

Anotācija