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The influence of NPK fertilization on *Lolium perenne* L. forage quality

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Abstract. Within the framework of the research program developed at the Latvian University of Agriculture (LLU), at the Research Institute of Agriculture (ZZI), Agency of LLU field trials were established and research was conducted over the period 1999–2003. In all trials, tetraploid perennial ryegrass cv. 'Spidola' was sown to plots at a rate of 12 kg ha^{-1}. The impact of three factors (NPK) in 17 treatments, replicated four times, were researched according to the so-called „star" scheme added to control treatment $N_0P_0K_0$ + absolute MAX $N_{120}P_{120}K_{160}$. The total plot area was 17.5 m^2, harvested area 13.5 m^2. In the trial, five levels of fertilizer were compared: – 0; 30; 60; 90 and 120 kg ha^{-1} of N, 0; 30; 60; 90 and 120 kg ha^{-1} of P_2O_5, and 0; 40; 80; 120 and 160 kg ha^{-1} of K_2O. The goal of current research was to clarify the influence of mineral fertilizer optimization on forage quality formation in perennial ryegrass cv. 'Spidola' under agro-climatic conditions of Latvia. It is concluded that N fertilizer mostly influenced herbage yield and quality characteristics of perennial ryegrass where both, crude protein (CP) content of dry matter and total yield of CP per hectare increased. In the treatments N_{60} and N_{120}, the CP content in grass dry matter increased by 0.14 and 2.66%, and CP yield per hectare by 98 and 226%, respectively, compared with N_0 (at P_{60} K_{80} background).

Key words: perennial ryegrass, fertilization**,** herbage quality

INTRODUCTION

Chemical composition of grass herbage is dependent on several factors: grass species and variety, phase of plant development, soil fertility and, particularly, nitrogen supply, fertilizer, meteorological conditions, timing of harvest and harvest technology. Herbage quality is formed under the influence and combination of these factors.

In Latvia, studies on grass herbage quality changes as influenced by different factors previously have been reported by many researchers (Pommers, 1956; Berzins et al., 2001; Runce, 1999; Heinackis, 1978; Adamovich et al., 1996). Literature findings suggest that the phase of plant development is the most important factor affecting protein content in herbage DM, but in grasses, the nitrogen fertilizer application rate is also significant (Adamovich et al., 1996).

According to the research results obtained by Berzins et al., (2002) in Skrīveri, CP content in perennial ryegrass varies between the cuts: 10–12% in the 1st cut and 10–15% in the re-growth.

The quality of forage grass is affected by the factors such as the species and variety of plants, sward age and utilization, fertilizer applied and diseases (Kadziulis, 1972; Fisher et al., 1993). Soil type is also a factor affecting the chemical composition (particularly the concentration of mineral nutrients) of grass. Plants are susceptible to specific nutrients' deficit in soil resulting in reduced growth intensity or insufficient uptake of the deficient element or both (Conrad et al., 1964).

Perennial ryegrass (*Lolium perenne* L.) is a most popular and economically important grass in temperate regions of the world. In Latvia, perennial ryegrass is also of great economic importance and is widely used in sown perennial grass swards and in pasture mixtures. Improvement of pasture productivity and quality of swards require additional knowledge about balanced mineral fertilizer use to increase perennial ryegrass forage quality. We have developed a new variety of perennial ryegrass 'Spidola' with improved growth in conditions in Latvia. Tetraploid ryegrass cultivar 'Spidola' was developed from diploid cultivar 'Priekuli 59' in the Skriveri Research Institute of Agriculture. 'Spidola' has improved winter hardiness and its vegetative growth period from start of growth to seed maturation is 115 days. It has shorter plant height with wider, darker leaves as compared with its parent cultivar. Our hypothesis was that, depending on weather and growth conditions and applied fertilizer rate, the characteristics of produced forage might vary. The objective of current work was to clarify the effect of applied mineral fertilizers on the forage quality of perennial ryegrass in different conditions in Latvia.

MATERIALS AND METHODS

Field trials were established and research was conducted within the framework of the research program developed by the Faculty of Agriculture (LF) of the Latvian University of Agriculture (LLU), at the Research Institute of Agriculture (ZZI).

Field experiments were carried out on sod-podzolic sandy soil (Luvic Phaeozem, WRB, 1998), pH_{KCl} 6.5, plant available P_2O_5 110 and K_2O 204 mg kg^{-1} (Enger–Riehm), soil organic carbon 12.2 g kg^{-1} (Tyurin's method). In the trials, in autumn of the year before sowing, the field was kept in bare fallow. Weed control was done by herbicide application (Roundup 4 l ha^{-1}). Each trial plot, laid out according to the trial scheme, received broadcast application of mineral fertilizers: phosphorus as granulated super-phosphate (20% P_2O_5) and potassium as potassium chloride (60% K_2O).

In the trials, tetraploid perennial ryegrass cv. 'Spidola' (germination 99%, seeding rate – 12 kg ha^{-1}) was sown to the plots (row spacing 12.5 cm) in mid-May using a seeder Nordsten. Weeds were controlled with herbicide MCPA 750 (1.5 L ha^{-1}) in a mixture with Granstar (10 g ha^{-1}) during all trial years.

In the field trials, the impact of three factors (NPK) as 17 treatments replicated four times was studied according to so-called 'star' scheme (Hike, 1967) added to control treatment $N_0P_0K_0$ + absolute max $N_{120}P_{120}K_{160}$. The total plot area was 17.5 m^2 (5 m × 3.5 m); harvested area – 13.5 m^2 (4.5 m × 3 m). For data processing, treatments were grouped and designated corresponding to the fertilizer rate applied. In the trial, five levels of fertilizers were compared: 0; 30; 60; 90 and 120 kg ha^{-1} of N, 0; 30; 60; 90 and 120 kg ha^{-1} of P_2O_5, and 0; 40; 80; 120 and 160 kg ha^{-1} of K_2O. Explanation of treatments, i.e. plant nutrients applied, is presented in Table 1.

Table 1. Crude protein yield in the 1st production year depending on fertilizer rate applied, kg ha^{-1}.

Treatment/Trial year	2000	2001	2002	Average
$N_0P_0K_0$	222	192	132	187
$N_0P_{60}K_{80}$	297	256	125	222
$N_{30}P_{30}K_{40}$	413	336	232	323
$N_{30}P_{30}K_{120}$	488	421	225	371
$N_{30}P_{90}K_{40}$	458	408	185	345
$N_{30}P_{90}K_{120}$	467	434	231	372
$N_{60}P_0K_{80}$	478	450	238	384
$N_{60}P_{60}K_0$	593	497	186	409
$N_{60}P_{60}K_{80}$	486	522	318	440
$N_{60}P_{60}K_{160}$	526	626	354	502
$N_{60}P_{120}K_{80}$	566	490	294	447
$N_{90}P_{30}K_{40}$	699	613	436	578
$N_{90}P_{30}K_{120}$	795	621	446	613
$N_{90}P_{90}K_{40}$	654	532	370	516
$N_{90}P_{90}K_{120}$	679	683	531	630
$N_{120}P_{60}K_{80}$	699	714	752	724
$N_{120}P_{120}K_{160}$	890	824	558	750
Average	548	502	319	452
$LSD_{0,05}$	56	49	48	48

Weather data recorded by the Skriveri meteorological station were used. In general, weather conditions during all trial period were comparatively favorable for the growth and development of perennial ryegrass. However, weather conditions were the most favourable for yield formation in 2002; adverse weather conditions in 2000 resulted in considerable fluctuation of dry matter yields and other parameters.

In the 1st production year, the fresh yield of grass was recorded in cut 1. Samples of fresh material were collected from an area of 1 m^2 in size. From each fertilizer treatment in 2 replicates, cutting the sward at early flowering, samples of fresh material 1 kg in weight were taken and weighed with precision of ± 0.01 kg. These samples were used for the determination of dry matter (DM) content.

Plant chemical analyses were performed in the analytical laboratory of the ZZI employing standard methods approved by the Latvian State. DM was determined by drying samples at 105°C till constant weight (ISO 6496), total nitrogen (TN) – by the Kjeldahl method (ISO 5983), crude protein (CP) – by multiplying total nitrogen content by coefficient 6.25. Crude fat (CF) was determined by the Soxlet method (GOST 1349.15–85), crude fiber – by Henneberg–Stohmann (GOST 13496.2–84), N-free extracts were calculated as the difference between total weight of a sample and humidity, crude ash, CP, CF and crude fibre content in plants. Dry matter digestibility (DMD) was calculated.

Data were statistically analyzed using analysis of variance and correlation analysis (Excel). Least significant differences between the means were calculated at $p < 0.05$.

RESULTS AND DISCUSSION

The herbage quality of grass is characterized by chemical composition, which is influenced by biological characteristics of plants, harvesting regime and growth factors. CP content is the main determinant of forage quality.

In current trials, the average content of CP and N-free extracts in grass dry matter was highest in 2000 10.89% and 58.45%, respectively. In subsequent years these characteristics were lower, while crude fibre content, on the average of the three years, was highest in 2002 – 28.76%. Accordingly, DMD was also lowest in 2002 – 50.37%, but the highest average crude fat content was recorded in 2001 – 3.12%.

Content and yield of CP produced by grass were greatly influenced by N fertilizer. At equal PK fertilizer background ($P_{60}K_{80}$), nitrogen rate N_{60} increased the CP content in grass dry matter by 0.14% as an average of the three years and its total yield by 218 kg ha^{-1}. The influence of nitrogen rate N_{120} increased the CP content on the average by 2.26% and the total yield by 502 kg ha^{-1} (Table 1).

Consequently, nitrogen fertilizer rate N_{60} provided an increase in CP yield by 98% compared with the untreated plots producing 3.6 kg CP per 1 kg N applied. The nitrogen rate N_{120} increased CP the yield by 226%, producing 4.2 kg CP per 1 kg N applied. Nitrogen fertilizer had strong positive effect also on the contents of crude protein and crude fat in perennial ryegrass herbage, as well as strong negative effect on the content of N-free extracts. Analyzing grass quality characteristics depending on P and K fertilizer stated that neither P nor K had any strong effect on the changes in quality indices studied (Table 2). Average crude fibre content of the three testing years varied within the range of 24.7% to 29.0%. Increasing the NPK rates caused insignificant increase in crude fibre content in perennial ryegrass.

Perennial ryegrass has high DM digestibility: in current trials it was 61% on the average of the three production years. Mean content of N-free extracts (NFE) across the three years was 54.1%. With the increasing N rates, NFE content in grass DM decreased because CP content increased.

Table 2. Correlation coefficients for grass dry matter yield and quality.

Plant nutrient/Trial year	2000	2001	2002	Average
		Dry matter yield		
N	0.90	0.87	0.92	0.95
P	0.47	0.42	0.24	0.39
K	0.41	0.50	0.40	0.46
		Crude protein content		
N	0.75	0.83	0.84	0.88
P	0.20	0.36	0.45	0.36
K	0.29	0.50	0.55	0.48
		Crude fibre content		
N	0.11	0.55	0.23	0.41
P	–0.04	–0.11	0.44	0.09
K	–0.05	0.24	0.28	0.20
		Crude fat content		
N	0.65	0.74	0.78	0.89
P	0.33	0.53	0.34	0.48
K	0.22	0.26	0.50	0.41
		N-free extracts		
N	–0.61	–0.82	–0.72	–0.81
P	–0.14	–0.27	–0.55	–0.36
K	–0.19	–0.49	–0.56	–0.46

CONCLUSIONS

Summarizing the results about the influence of mineral fertilizers on the quality of perennial ryegrass herbage, it is concluded that grass quality indices were mostly influenced by the rate of N fertilizer, by what the protein content in grass dry matter and its total yield per hectare increased considerably. In the treatments N_{60} and N_{120} (at $P_{60}K_{80}$ background) the crude protein content in grass dry matter increased by 0.14 and 2.66% and the crude protein yield per hectare by 98 and 226%; respectively. Increased N fertilizer rates contributed more to the increase of crude protein level and yield than to the increase of grass dry matter yield.

Effect of the phosphorus and potassium fertilizer applications to the swards depended on the PK reserves in the soil.

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