INFLUENCE OF NITROGEN FERTILIZER ON PERENNIAL GRASS DRY MATTER YIELD AND SUITABILITY FOR HEAT PRODUCTION

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Abstract. *Nowadays agriculture requires high-quality perennials with specific chemical composition that allows using them in bioenergy production. Sufficient amount of nutrients ensures favourable conditions for long-term use of soil resources and for high crop yield. Fertilizers along with climatic and soil conditions are vital for crop productivity and for yield quality. Nitrogen is significant for plant life processes; it is one of the main nutrients for grasses, it is important for yield and yield quality. Production of heat requires growing of plants with high biomass, high combustion ability, high heat output and low ash content. The aim of the research was to study dry matter yield of RCG and tall fescue depending on N fertilizer doses applied and to analyse the suitability of RCG and tall fescue dry matter yield for biofuel (pellet) production. In 2011-2012, the field trial was conducted in the Research and Study Farm "Pēterlauki". During the research, the influence of different doses of nitrogen fertilizer on the dry matter yield of reed canary and tall fescue had been analysed. It was found out that application of N more than 30 kg ha^{-1} allowed to increase the dry matter yield of reed canary grass by 1.08-3.93 t ha^{-1} or by 21.05-75.44%. For tall fescue, application of N more than 30 kg ha^{-1} allowed to increase the dry matter yield by 1.94-6.94 t ha^{-1} or by 21.64-119.1%.*

Key words: *perennial grass, dry matter yield, nitrogen.*

INTRODUCTION

In grass cultivation, specific attention should be devoted to biomass production and energy performance. Only productive grass is able to ensure positive energy balance in production of biofuel. Various species of grasses (*Poaceae*) may be grown for biomass production. In comparison with legumes, the productive longevity of grasses is higher. Grasses are less demanding for soil fertility and moisture regimes, produce high yields (up to 8-12 t ha^{-1}) and are perennial plants (up to 10 years) [1],[2].

Such grass species as reed canary grass (RCG) (*Phalaris aruindinacea* L.), tall fescue (*Festuca arundinacea* Schreb.), festulolium (× *Festulolium* Asch & Graebn.), meadow fescue (*Festuca pratensis* Huds.), timothy (*Phleum pratense* L.) are considered to be more suitable for bioenergy production [3],[1],[2].

Nitrogen (N) is significant for plant life processes; it is one of the main nutrients for grasses, it is important for yield and yield quality. An optimal N fertilizer dose is one that, when being increased, it does produce higher yield, but does not have negative influence on environment [4]. Fertilizing, agro-climatic and soil conditions are factors of a major significance for yield and quality of plants. Fertilizers allow acquiring higher yields. RCG biomass currently is considered to be one of the alternative sources for pellet production within the territory of Latvia, in Baltics and Northern Europe. These species are characterised with persistence to local climatic conditions and high biomass yield.

Effective use of nutrients is important for sustainable agricultural production. Sufficient amount of nutrients ensures favourable conditions for long-term use of soil resources and for high crop yield. Fertilizers along with climatic and soil conditions are vital for RCG productivity and for yield quality. The European Union sets high targets for the production of biofuels. This requires high energy yields and efficient use of available agricultural land [4],[1].

Heat production needs crops with high biomass, good combustion ability, heat output and low ash content. Ash is an indicator for the amount of non-combustible minerals in fuel. It is composed by minerals that do not burn during fuel combustion, i.e. those are inorganic substances [5]. Too high volume of ash leads to problems with automation of burning process, in addition thermal capacity of such solid fuel is by 600-1000 kJ kg^{-1} lower [5]. Ash content for grasses may comprise 1-20%; it may be affected by species, soil texture, moisture, mowing time. Standards set that ash content in timber should be 1.5%. Combustion heat of fuel is significant quality indicator that mostly depends on moisture and ash content. With average pellet moisture 6.7-7.8% it varies

between 18400 kJ kg^{-1} and 17700 kJ kg^{-1} [5]. Ash content in RCG is much higher than in wood materials (0.5-3.0%), while notably lower than in coal (approximately 25%) [6]. Ash content in grass biomass is significantly higher than in timber [7].

Use of RCG for heat production is characterized by major problems in burning process, such as potassium corrosion in superheaters; reduction of ash melting point; high quantities of ash that may affect mechanism of pyrolysis. Herbaceous fuels (also RCG) contain potassium as their principal ash-forming constituents. Potassium is the dominant source of alkali in most biomass fuels [8].

One of the most important problems encountered in Latvia agriculture is acquisition of high-quality perennial grass plants with definite chemical content, ensuring that they may be used for the production of bio-energy, i.e. solid fuel (pellets, briquettes).

Cultivation of grasses for production of pellets and briquettes has recently become successful industry in Europe. Grass pellets have great potential in energy production, as these are small-sized and may be produced and consumed in one particular place. Pelleted grass thereof may become main fuel in Latvia regions, rural municipalities and small businesses. Main benefit of grass cultivation and utilisation is a decrease of carbon dioxide emitted during whole production process [2].

The aim of the research was to study dry matter yield of RCG and tall fescue depending on N fertilizer doses applied and to analyse the suitability of RCG and tall fescue dry matter yield for biofuel (pellet) production.

MATERIALS AND METHODS

The objects of research were two perennials: reed canary grass (*Phalaris arundinacea* L.) and tall fescue (*Festuca arundinacea* Schreb.). They are yielding for 8-10 years, have plant length up to 1.5 m, they are unpretentious for soil and may grow on marginal lands. Moreover, they are suitable for cultivation in moisture meadows, have strong root system and excel with cold tolerance, high yields [1],[2].

The field trial was carried out during 2011–2012 in research and study farm "Pēterlauki" (56°53'N, 23°71'E) of the Latvia University of Agriculture. Samples were grown in sod calcareous soil with pH_{KCl} 6.7, containing 52 mg kg^{-1} P_2O_5 and 128 mg kg^{-1} K_2O, organic matter content 21-25 g kg^{-1}. Nitrogen fertilization in the amount of 0, 30, 60, 90, 60+60, 75+75, 90+90 kg ha^{-1} was applied. Split doses of nitrogen fertilizers were applied first time at the beginning of spring vegetation and second time after first cutting. At the start of vegetation 80 kg ha^{-1} P_2O_5 and 120 kg ha^{-1} K_2O were used. Seed sowing norm was 1000 germinant seeds per 1 m^2; usage type: mowing two-three times.

Ash content in different samples was found out in the agricultural scientific laboratory for agronomic analyses of the University of Latvia in compliance with the ISO 5984: 2002/Cor 1: 2005 standard. The volume of sulphur and carbon in pellet samples was found out by using analyser "Eltra CS-500 Analizator". Lignin was measured in line with LVS EN ISO 13906:2008, ash in compliance with ISO 5984:2002/Cor 1 : 2005, wood fibre according to ISO 5498 : 1981, acid detergent fibre (ADF) with LVS EN ISO 13906 : 2008, nitrogen with LVS EN ISO 5983 – 2 : 2009, and potassium in line with the LVS EN ISO 6869:2002. For each sample three parallel experiments were carried out, repeating each tested combination three times. The correlations were analysed as linear or polynomial regressions, and graphs were made using MS Office program Excel.

RESULTS AND DISCUSSION

Dry matter is a combustible part of solid fuel; therefore dry matter yield is very important for heat production as it serves as an indicator for evaluation of suitability of biomass for fuel production. The volume of energy depends on the dry matter yield. Nitrogen (N) fertilizers are very significant for increasing biomass productivity, because it is the key plant nutrient for plant growth and development. The results showed that increased N fertiliser dose promotes higher dry matter yield. N fertilizer in all versions left positive effect on dry matter yield (Fig. 1). The application of N more than 30 kg ha^{-1} allowed to increase the dry matter yield of reed canary grass by 1.08-3.93 t ha^{-1} or by 21.05-75.44%. For tall fescue, application of N more than 30 kg ha^{-1} allowed to increase the dry matter yield by 1.94-6.94 t ha^{-1} or by 21.64-119.1%. The highest RCG dry matter yield (9.06 t ha^{-1}) was produced with N fertilizer dose 90+90 kg ha^{-1}. The highest tall fescue dry matter yield (11.24 t ha^{-1}) was produced with N dose 60+60 kg ha^{-1}, however with bigger N dose (75+75 or 90+90 kg ha^{-1}) the tall fescue dry matter yield reduced.

Ash is what remains when biomass fuel is burnt; for timber it is approximately 0.5%, while for agricultural products, e.g., straw, remaining ash amount reaches even 12% [10]. The results showed that ash content

in this research (with various N fertiliser doses) in RCG dry matter yield was 7.02-8.88 %, while for tall fescue it was 7.93-8.88%. Low positive correlation between the ash content and the dry matter yield was found (Fig. 2).

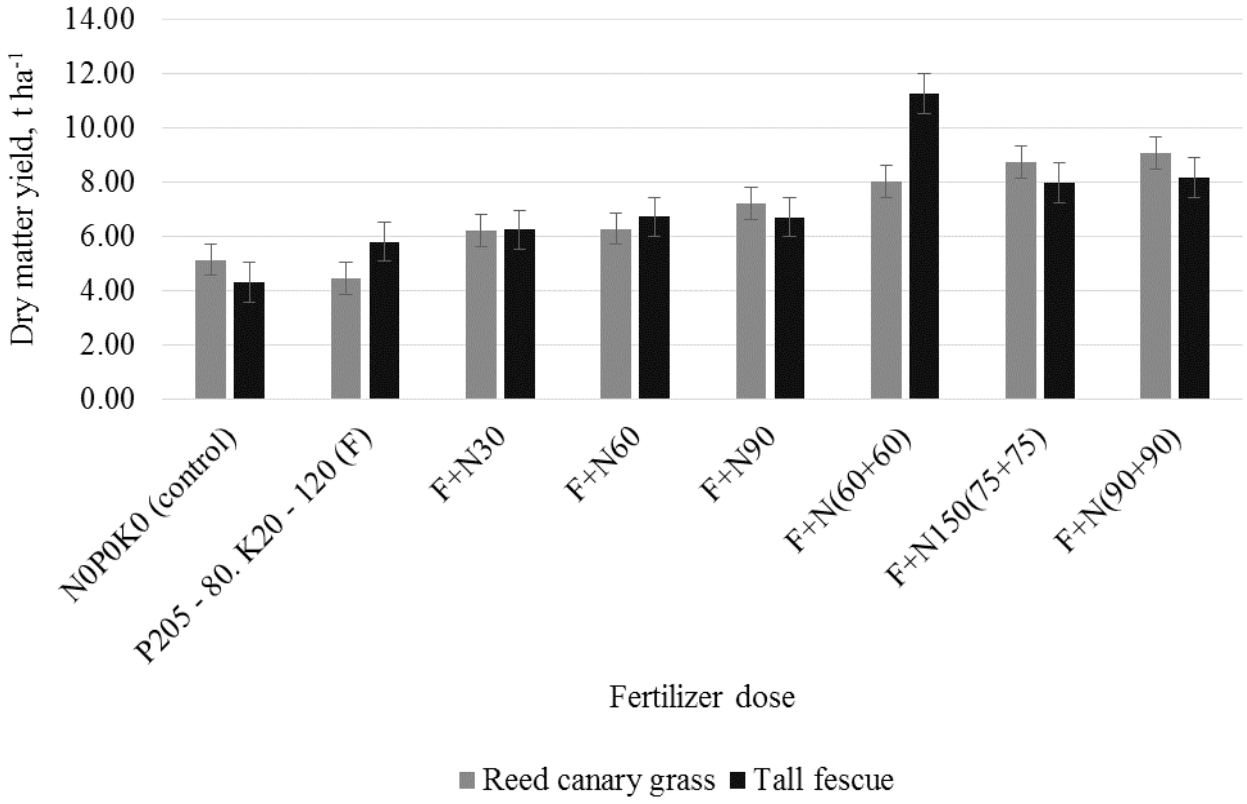

Figure 1. **Average dry matter yield of reed canary grass and tall fescue depending on nitrogen fertilizer dose**

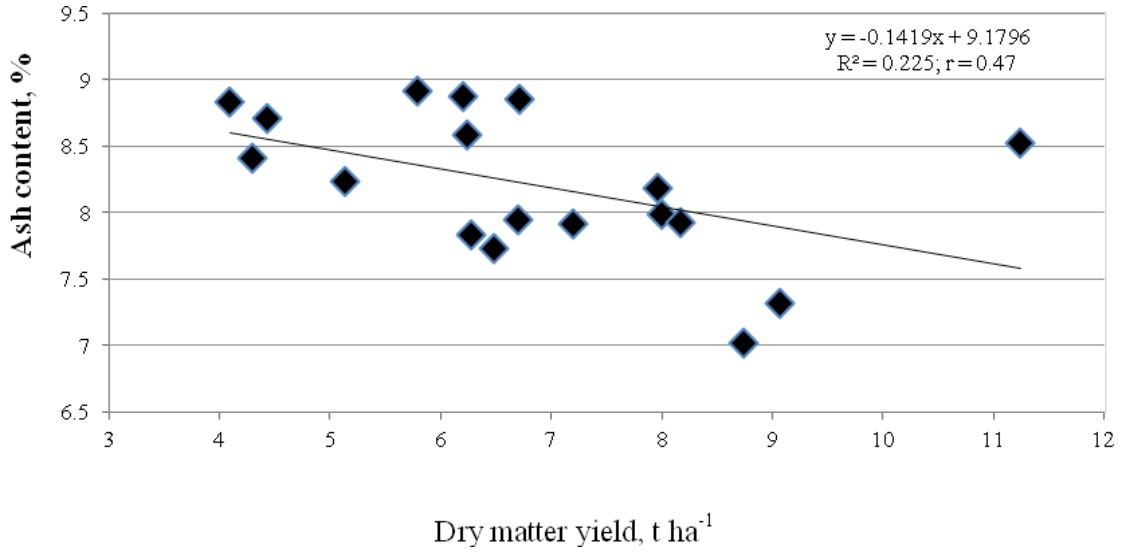

Figure 2. **Ash content in reed canary grass and tall fescue depending on dry matter yield**

For comparison, research conducted in Lithuania have found out that N fertilizers diminish ash content in crop biomass [11].

The results showed that application of N more than 60 kg ha^{-1} allowed to decrease the ash content of reed canary grass by 0.25-1.22%. For tall fescue, application of N 90 kg ha^{-1}, 150 (75+75) kg ha^{-1}, 180 (90+90) kg ha^{-1} allowed to decrease the dry matter yield by 0.46%, 0.23% and 0.48% respectively.

It was observed that 85–95% of plant nutrients (Ca, Mg, K, P) in ash (from burning of solid biofuel) occur in "usable ash" mixture of bottom and cyclone fly ash [12].

Significant correlation between dry matter yield and ash, phosphorus and carbon content was found for RCG. For the tall fescue, significant correlation between dry matter yield and potassium or sulphur content was found (Table 1). It means that application of N fertilizers does not have effect on grass biomass utilisation for heat production.

Table 1

Correlations between dry matter yield and fuel parameters for reed canary grass and tall fescue

Fuel parameters	Reed canary grass		Tall fescue biomass	
	R^2	Regression equation	R^2	Regression equation
Ash, %	0.622	y = -0.3011x + 10.018	0.1099	y = -0.0576x + 8.856
Lignin, %	0.0074	y = -0.015x + 5.1361	0.0536	y = -0.042x + 5.6499
Nitrogen (N), %	0.1222	y = 0.0163x + 0.8452	0.1815	y = 0.0221x + 0.7819
Phosphorus (P), %	0.8303	y = -0.0134x + 0.397	0.2701	y = -0.0035x + 0.2663
Potassium (K), %	0.0031	y = 0.002x + 1.8929	0.6773	y = 0.0726x + 1.5562
Carbon (C), %	0.6171	y = 0.1337x + 46.653	0.0003	y = -0.0024x + 46.245
Sulphur (S), %	0.3482	y = -0.0018x + 0.0822	0.5229	y = -0.0042x + 0.1155
Wood fibre, %	0.2023	y = 0.2616x + 29.648	0.001	y = -0.0206x + 31.65

Dry matter yield has effect on the choice of combustion technology, as well as it influences on total biomass energy transformation costs [10]. German scientists [13] in research on multivariate regression analysis proved that biomass quality parameters are influenced by yielding time and climatic conditions (rain) present during the whole growing period [13].

As compared to other researches, ash content found within this research is slightly higher and ranges between 8 and 8.5%, while lignin content is lower – only 5-5.4%. Therefore, utilisation of biomass gives importance to technologies ensuring higher efficiency during combustion. Agro-climatic conditions of Latvia are suitable for cultivation of RCG and tall fescue and production of high yields. As compared to other alternative energy sources, RCG and tall fescue biomass may become main fuel used in Latvia counties and small businesses.

CONCLUSIONS

The application of N more than 30 kg ha^{-1} allowed to increase the dry matter yield of reed canary grass by 1.08-3.93 t ha^{-1} or by 21.05-75.44%. For tall fescue, application of N more than 30 kg ha^{-1} allowed to increase the dry matter yield by 1.94-6.94 t ha^{-1} or by 21.64-119.1%.

The highest RCG dry matter yield (9.06 t ha^{-1}) was produced with N fertilizer dose 90+90 kg ha^{-1}. The highest tall fescue dry matter yield (11.24 t ha^{-1}) was produced with N dose 60+60 kg ha^{-1}, however with bigger N dose (75+75 or 90+90 kg ha^{-1}) the tall fescue dry matter yield reduced.

The application of N more than 60 kg ha^{-1} allowed to decrease the ash content of reed canary grass by 0.25-1.22%. For tall fescue, application of N 90 kg ha^{-1}, 150 (75+75) kg ha^{-1}, 180 (90+90) kg ha^{-1} allowed to decrease the dry matter yield by 0.46%, 0.23% and 0.48% respectively.

The application of nitrogen fertilizers does not have effect on grass biomass utilisation for heat production.

The dry matter yield has high ash content, therefore it would be useful to produce pellets from grass biomass, mixing it with wood, since that would reduce ash content (one of the key problems in combustion process causing problems for heating system).

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