INFLUENCE OF FERTILIZERS ON CHEMICAL CONTENT OF ENERGY GRASS BIOMASS

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Abstract. Perennial grasses are a good option for biofuels because they do not have to be planted annually and do not require application of agricultural chemicals. Since the crop value for bioenergy use is the carbohydrates, not the protein, the grasses can be harvested after they have died back in the fall, i.e., after the nitrogen and other nutrients have been translocated back into the roots and crowns. So late harvesting means that the nutrients remain in the perennial parts of the plants, which, in turn, means that the crop does not need high levels of fertilization each year. The chemical composition of grasses is very dynamic, and it changes significantly during the vegetation period. When using grass biomass for solid fuels, the chemical composition of grasses is of major importance, as alkali metals affect the ash melting temperature. One of the key parameters is nitrogen content in fuel, which affects the formation of NOx emissions. The aim of the research was to assess the effect of nitrogen fertiliser norms on the chemical composition of grass biomass. The research objects were reed canary grass (RCG) (*Phalaris arundinacea* L.), tall fescue (*Festuca arundinacea* Schreb.), and timothy (*Phleum pratense* L.) – the perennial and productive plants of the grass family. Increasing the fertiliser norms from N0 to N90, the content of non-combustible element N in the biomass of all grasses also increased. However, nitrogen fertiliser has little yet significant impact on the content of combustible element C in grass biomass.

Keywords: energy grass, biomass, fertilizers, the content of carbon, nitrogen, and potassium.

Introduction

Determination of biomass composition is an important stage before its combustion, as chemical composition determines the characteristics and quality of fuel, potentially applicable technologies, and emissions that form during fuel combustion [1].

Carbon has a high calorific value, and it constitutes a significant part of combustible mass [2]. However, during combustion, it generates carbon dioxide (CO and CO_2) emitted into the atmosphere. The content of carbon dioxide (CO) in flue gases must not exceed 0.05 % [3]. Perennial crops have higher carbon sequestration [4].

Potassium content in biomass reduces the ash melting temperature [1, 5]. Moreover, K in biomass can be emitted with Cl as KCl, which will promote corrosion, as well as in the form of small particles [6].

During combustion, all fuel nitrogen forms into N_2 and nitrogen oxides NOx (NO, NO_2) [7]. The key parameters affecting the formation of NOx emissions are the nitrogen content in fuel, excess air coefficient (α), furnace structure, combustion temperature, and the combustion technology type [5, 8].

The increased content of potassium, calcium, magnesium and sodium in grass biomass, in comparison with wood, is explained by the application of pesticides and fertilizers [1, 7]. Therefore, it is essential to determine the effect of nitrogen norms on the chemical composition of the biomass of the grasses – reed canary grass, timothy, and tall fescue.

The aim of the research was to assess the influence of the nitrogen norms on the chemical composition – carbon (C), nitrogen (N), and potassium (K) – of energy crop biomass in two harvesting years.

Materials and methods

The research objects were reed canary grass (*Phalaris arundinacea* L.), tall fescue (*Festuca arundinacea* Schreb.), and timothy (*Phleum pratense* L.). A field trial was carried out in the Research and Study Farm "Pēterlauki" (56°53'N, 23°71'E) of the Latvia University of Agriculture (LLU) in 2011-2013. The soil was sod calcareous, pH KCl 6.7, containing available for plants P 52 $mg \cdot kg^{-1}$ and K 128 $mg \cdot kg^{-1}$; the organic matter content was 21 to 25 $g\ kg^{-1}$ of soil. Harvesting period: 2012-2013.

Treating energy grasses with four different fertiliser norms ($kg \cdot ha^{-1}$): 1) N0P0K0; 2) N30P80K120; 3) N60P80K120; and 4) N90P80K120. Each fertiliser norm was repeated three times.

The fertiliser norms used in the research and their designations are shown in Table 1.

Table 1

Characterization of fertilizer norms

N, kg·ha^{-1}	P_2O_5, kg·ha^{-1}	K_2O, kg·ha^{-1}	Designation in the text
0	0	0	N0
30	80	120	N30
60	80	120	N60
90	80	120	N90

The chemical composition of biomass was determined in the Agricultural Scientific Laboratory for Agronomic Analyses of the LLU: potassium level – in compliance with LVS EN ISO 6869:2002; nitrogen level – in compliance with LVS EN ISO 5983-2:2009; and carbon level – with the CS-500 analyser.

Agrometeorological conditions. In April, the revegetation of grasses begins; in the second half of April, the development of grass plants is rapid. In April 2013, the air temperature was 1.2°C lower than Jelgava's perennial indicators (the average margin). The amount of rainfall in 2012 and 2013 was lower than the average annual levels. The fertilizer was applied in the second ten-day period of May. The average daily air temperature in the second ten-day period of May was above 11.5°C. Insufficient precipitation was observed in 2012, whereas in other research years, it was above 16.7 mm. In June, the grass flowering phase was observed when the average air temperature was close to the average annual rates and the rainfall level was insufficient. In the first ten-day period of June 2012, cool weather was observed and the amount of rainfall was 72 % of the average annual rates. In the second ten-day period of June 2012 and 2013, warm and sunny weather prevailed and the amount of rainfall did not exceed the average annual precipitation rates. In September in all research years, the average amount of rainfall was insufficient, except the year 2013, when precipitation was 197 % of the norm. To summarize, the air temperature in all research years can be characterized as warm, as it was higher than the average annual rates.

Results and discussion

Carbon content in energy crops is a significant indicator, as carbon is a combustible element. The higher the level of carbon, the higher the heat of combustion. Grass plants used in the research had the following carbon content: reed canary grass – 45.06 ± 0.28 %; tall fescue – 44.47 ± 0.32 %; and timothy – 45.54 ± 0.22 % (Fig. 1).

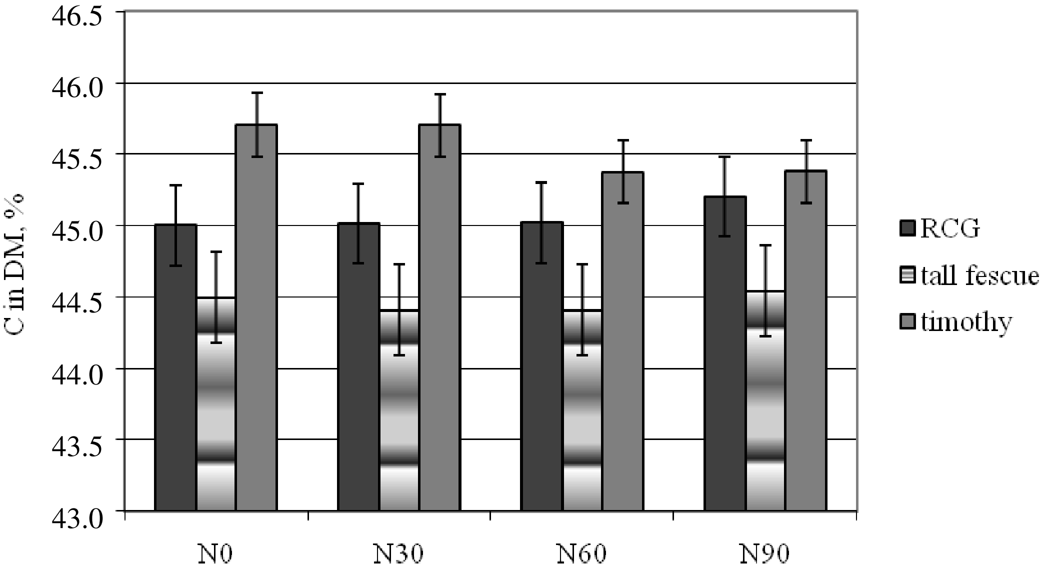

Fig. 1. **Carbon content in grass biomass depending on the nitrogen fertilizer norm**

Also other studies have shown that the carbon content differs within various genera of one family, within various sorts of one species, and even within parts of a single plant [9; 10]. D. Lazdiņa, A. Lazdiņš, and A. Bārdulis [11], the scientists of the Latvian State Forest Research Institute "Silava", have found that the dry matter of reed canary grass contains 49 % of carbon. The biologists T. G. Bridgeman, J. M. Jones, I. Shield, and P. T. Williams Williams [12] have very similar results, i. e., according to their findings the carbon content in reed canary grass is 48.6 %.

Potassium is also an essential element, ensuring vital biological processes in plants. In 2012 and 2013, the average content of potassium in reed canary grass biomass was 2.17 ± 0.11 %, in tall fescue biomass – 2.41 ± 0.09 %, and in timothy biomass – 2.50 ± 0.08 % (Fig. 2).

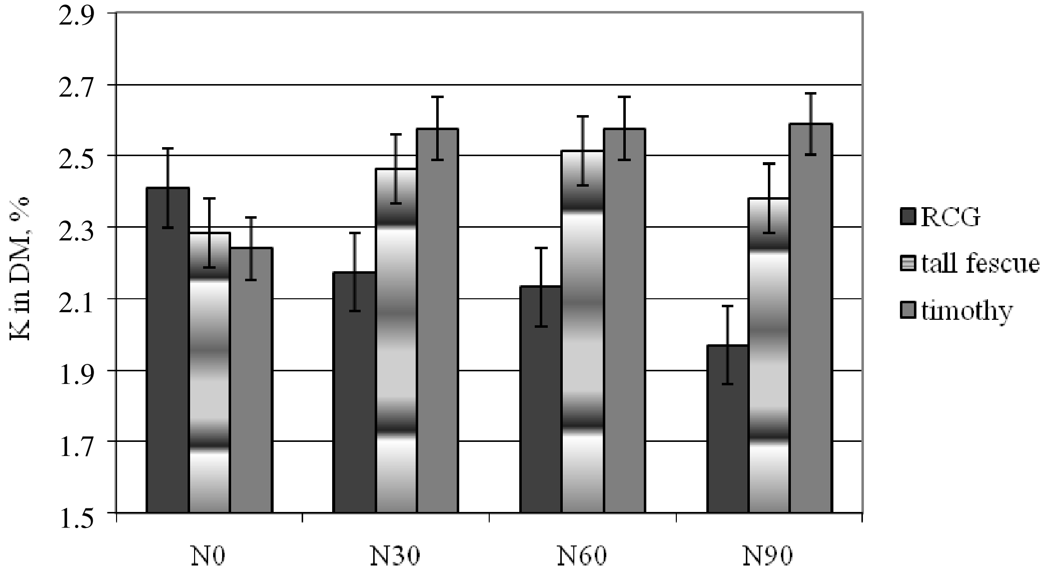

Fig. 2. **Potassium content in grass biomass depending on the nitrogen fertilizer norm**

Nitrogen content in reed canary grass was 1.15 %±0.13 %, in tall fescue – 0.99 ± 0.09 %, and in timothy – 1.15 ± 0.11 % (Fig. 3); whereas the suggested maximum nitrogen content in biomass fuel is below 0.6 % [8].

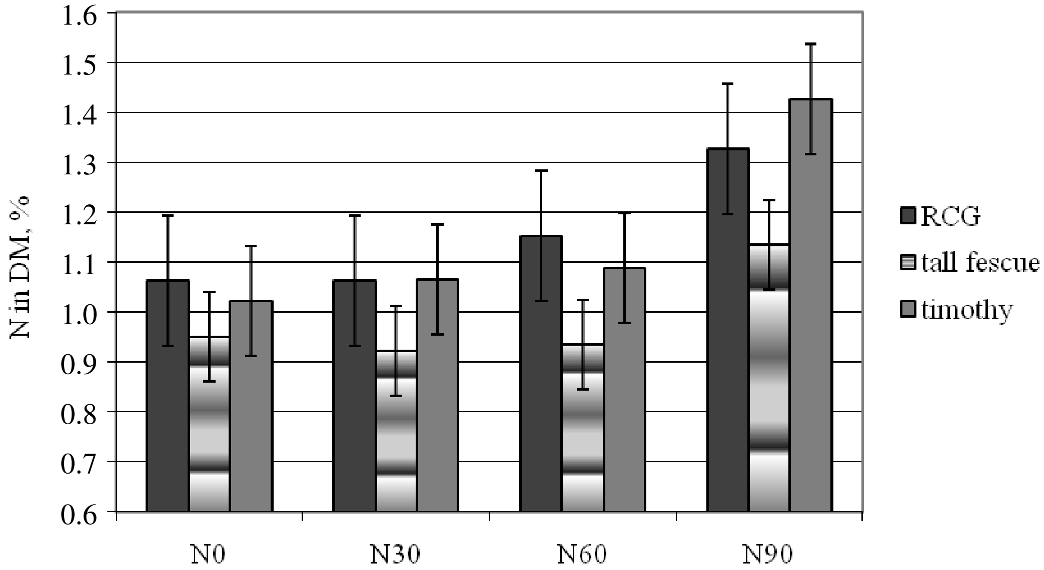

Fig. 3. **Nitrogen content in grass biomass depending on the nitrogen fertilizer norm**

Increasing the nitrogen fertiliser norm from N0 to N90 did not increase the potassium content, but minimally reduced the carbon content (by 0.03 %) and increased the nitrogen content (by 0.29 %). However, assessment of the nitrogen fertiliser's influence on each separate species and each chemical element demonstrates that nitrogen slightly yet very significantly affects the carbon content in plants. Agrometeorological conditions in the growing year had a significant ($p<0.001$) effect on the content of K, C, and N in the biomass of reed canary grass, tall fescue, and timothy (Table 2).

Table 2

Percentage of factors' effect, %

Factor	Reed canary grass			Tall fescue			Timothy		
	C	K	N	C	K	N	C	K	N
Nitrogen fertiliser (F_A)	0.4*	21.2**	23.1*	0.8*	3.6**	54.2**	0.5*	7.7**	30.8**
Agrometeorological conditions in 2012–2013 (F_B)	99.2**	46.6**	61.3**	98.2**	92.8**	25.6**	99.0**	79.9**	32.7**
Correlation between (F_A) and (F_B)	0.3*	31.2**	12.4**	0.7*	3.2**	13.9*	0.5*	12.1**	35.0**

*p<0.001; **p<0.05

Potassium content depends not only on the agrometeorological conditions but also on the correlation between the air temperature, precipitation, and the nitrogen fertilizer norm.

Conclusions

1. The research revealed that timothy biomass had the highest carbon content – 45.54 %±0.22 %, but tall fescue had the lowest carbon content – 44.47 %±0.32 %. Potassium content was higher in timothy biomass – 2.50 %±0.08 % – but lower in reed canary grass biomass – 2.17 %±0.11 %. Nitrogen content was similar in both reed canary grass and timothy biomass – 1.15 %±0.13 % and 1.15 %±0.11 % respectively, while tall fescue biomass had lower nitrogen content – 0.99 % ±0.09 %.
2. The chemical composition of grass biomass was affected more by the agrometeorological conditions and nitrogen fertilizer during the growth period.
3. Increase from N0 to N90 in the nitrogen fertiliser norm on grasses significantly affected the content of combustible element C in biomass and increased the content of non-combustible element N.

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References

1. Vassilev S. V., Baxter D., Andersen L. K., Vassileva C. G. An overview of the chemical composition of biomass, Fuel, No. 89, 2010, pp. 913–933.
2. Cars A. Energoresursi (Energy resources), Rīga, SIA Baltic Communication Partners, 2008, 102 p.
3. Ministru kabineta noteikumi Nr. 534. Noteikumi par Latvijas būvnormatīvu LBN 231-03 "Dzīvojamo un publisko ēku apkure un ventilācija" (Buildings, heating and ventilation for Residential and Public), Latvijas Vēstnesis, Nr. 132, 2003, http://likumi.lv/doc.php?id=79290 (In Latvian)
4. Sartori F., Lal R., Ebinger M. H., Parrish D. J. Potential soil carbon sequestration and CO_2 offset by dedicated energy crops in the USA. Critical Reviews in Plant Sciences, No. 25, 2006, pp. 441-472.
5. Kalnačs J., Grehovs V., Grigale D., Murašovs A., Orupe A. Koksnes un augu pelnu sastāvs un īpašības, videi labvēlīgas utilizācijas iespējas (Wood and plant ash composition and properties of environmentally sound disposal options), International conference: Eco-Balt, Rīga, 2008, 69 p. (In Latvian)
6. Lewandowski I., Kicherer A. Combustion quality of biomass: practical relevance and experiments to modify the biomass quality of *Miscanthus* × *giganteus*, European Journal of Agronomy, No. 6, 1997, pp. 163-177.
7. Williams A., Jones J. M., Ma L., Pourkashanian M. Pollutants from the combustion of solid biomass fuels, Progress in Energy and Combustion Science, No. 38, 2012, pp. 113-137.

8. Obernberger I., Brunner T., Barnthaler G. Chemical properties of solid biofuels – significance and impact, Biomass and Bioenergy, No. 30, 2006, pp. 973-998.
9. Belicka I., Miglāne V., Jansone Z. Vasarāju graudaugu sugu piemērotība siltumenerģijas ražošanai (Suitability of spring cereals for production of heat energy), Environment. Technology. Resources. Proceedings of the 7th International Scientific and Practical Conference, Vol. 1, Rezekne, 2009, pp. 24-30 (In Latvian)
10. Čubars E., Noviks G. Evaluation of reed resources in the Lubans lake and substantiation of their use in energy production, Enviroment. Technology. Resources: Proceedings of the 7th International Scientific and Practical Conference, Rezekne, Vol. 1, 2009, pp. 66-73.(In Latvian)
11. Lazdiņa D., Lazdiņš A., Bārdulis A. Daudzgadīga stiebrzāļu energokultūra – miežabrālis (Perennial grasses energy crop – reed canary grass), Silava, 2008, 10 p. (In Latvian)
12. Bridgeman T. G., Jones J. M., Shield I., Williams P. T. Torrefaction of reed canary grass, wheat straw and willow to enhance solid fuel qualities and combustion properties, Fuel, No. 87, 2008, pp. 844-856.