INFLUENCE OF NITROGEN FERTILIZER ON GRASS BIOMASS YIELD AND AMOUNT OF ENERGY GAINED PER AREA UNIT

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Abstract. Sustainability of biomass is characterized by its composition, physical properties and other qualitative parameters such as the amount of area required for gaining a unit of biomass energy – GJ·ha^{-1}·year^{-1} –, which strongly depends on the productivity (i.e., yields per area unit) of the managed ecosystem. Perennial grasses are essential for the agricultural production sector in Latvia. The nature and extent of winter damage on grasslands highly dependupon the climatic conditions, moreover, it influences both persistency and the yield. Scientists have found that plant biomass is one of the best sources that may be used for the production of solid biofuels. The field trials were carried out in sod calcareous soils in 2011–2014. The following grass cultivars were used: reed canary grass (*Phalaris arundinaceae* (L.) Raush.), festulolium_(×*Festulolium* Asch. & Graebn.), timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis)* Huds.), and tall fescue (*Festuca arundinaceae* Schreb.). Fertilizers applied: main fertilizer (F) – P80K120 kg·ha^{-1}; and six additional nitrogen fertilizers: F + 30, F + 60, F + 90, F + 120, F + 150, and F + 180 kg·ha^{-1} N. In our study, the highest energy yield per 1 ha was obtained from tall fescue (119.8 GJ·ha^{-1}) and timothy (145.3 GJ·ha^{-1}), when 180 kg·ha^{-1} of nitrogen fertilizer were applied, which was 54 % and 73 % more, respectively, compared to the unfertilized plots.

Keywords: nitrogen, fertilizer, perennial grasses, energy yield.

Introduction

Grasses are an important crop group suitable for growing under agro-climatic conditions of Latvia, and they possess a small energy capacity. The production of grass biomass for fuel production is becoming increasingly popular in all Europe, and its introduction is lucrative for farmers. It takes only 70-80 days to grow grass biomass for energy [1; 2].

A survey of biomass supply in Europe showed that multi-year grasses had the highest biomass potential [3].

In 2007, the energy output from pure reed canary grass fields in Estonia amounted to 144 GJ·ha^{-1}, while in spring it was 116 GJ·ha^{-1} [4]; whereas in Lithuania, pure reed canary grass fields produced an average of 115-130 GJ·ha^{-1} [5].

At the conference of the Latvian Biogas Association, Andis Kārkliņš [6] referred to the data in Indulis Emsis' report: "There is the following amount of energy extraction possibilities from 1 ha per year in Latvia: forest (wood growth) – 26.8-33.5 GJ·ha^{-1}; crop plants (biogas) – 100-150 GJ·ha^{-1}; biodiesel (from rape seed) – 37-45 GJ·ha^{-1}; and fuel bioethanol (from grains) – 27-36 GJ·ha^{-1}".

The objective of the study was to clarify how the energy value of grass biomass varies depending on the calorific value and dry matter yield of grasses.

Materials and methods

Field trials were set up at the study and research farm "Pēterlauki" (56º53' N, 23º71' E) of the Latvia University of Life Sciences and Technologies (LLU) in 2011. Soil: sod calcareous soil LUVISOLS (according to the FAO classification). Granulometric composition: heavy dusty sand clay. Soil agrochemical parameters: pH KCL 6.7 (LVS ISO 10390: 2006); organic matter content – 21 g·kg^{-1} (by Tyurin method; LV ST ZM 80-91); phosphorus content – 52 mg·kg^{-1} P_2O_5, and potassium content – 128 mg·kg^{-1} K_2O (according to the Egner-Rhym method; LV ST ZM 82-97).

The following grass cultivars were used: reed canary grass (*Phalaris arundinaceae* (L.) Raush.) cultivar "Marathon", festulolium_(×*Festulolium* Asch. & Graebn.) cultivar "Vetra", timothy (*Phleum pratense* L.) cultivar "Teicis", meadow fescue (*Festuca pratensis)* Huds.) cultivar "Vaira", and tall fescue (*Festuca arundinaceae* Schreb.) cultivar "Fawn".

Grasses were sown in May 2011 without a cover crop, in three replications, within a 10 m^2 plot size.

Fertilizers applied: main fertilizer (F) – P80K120 kg·ha^{-1}; and six additional nitrogen fertilizers: F + 30, F + 60, F + 90, F + 120, F + 150, and F + 180 kg·ha^{-1} N.

Nitrogen fertilizer was ammonium nitrate (NH_4NO_3), phosphorus fertilizer was simple granular superphosphate (Ca (H_2PO_4) 2 · $H_2O + CaSO_4$), and potassium fertilizer was potassium chloride (KCl). No mineral fertilizers were used in the sowing year.

The highest calorific value (*Qa*) for different grass species was determined by the standard ISO 1928, LVS EN 14918 "The laboratory of waste and fuel exploration and testing "Virsma"" in five replications for each species. The highest calorific value of grass and wood biomass was used to calculate the amount of the energy produced. The energy value of pellets was calculated using the following formula [7] (1):

$$Q_{kop} = Q_a \cdot M_s, \tag{1}$$

where Q_{kop} – total amount of energy obtained from 1 ha, MJ·ha^{-1};
Q_a – highest calorific value of biomass dry matter, MJ·kg^{-1};
M_s – mass of biomass dry matter of 1 ha, kg·ha^{-1}..

Results and Discussion

Compared to fossil resources, biomass is the cheapest raw material for fuel [8]. Most useful for energy production are crops that produce high dry matter yields (t ha^{-1}) at low costs [9; 10].

Dry matter yield depends on the use of nitrogen fertilizer. A significant yield increase for canary reed grass, meadow fescue and tall fescue was obtained using 60 kg·ha^{-1} of N, for festulolium – 90 kg·ha^{-1} of N, and for timothy – 120 kg·ha^{-1} of N when background PK fertilization was 80 kg·ha^{-1} of P_2O_5 and 120 kg·ha^{-1} of K_2O (Table 1).

Table 1

Influence of nitrogen fertilizer on grass dry matter yield (average in 2012-2014)

N norms, kg·ha^{-1}	Dry matter yield, t·ha^{-1}							Relative variation of yield, %
	Grass species					Average	*Sx*	
	reed canary grass	festulolium	timothy	meadow fescue	tall fescue			
0	5.20	4.89^{c}	4.96^{c}	4.52^{c}	5.11	4.94	± 0.12	100
30	6.09^{a}	5.64^{a,c}	5.86^{a,c}	5.39^{a,c}	5.74^{a,c}	5.74	± 0.12	116
60	7.01^{a}	6.45^{a,c}	6.79^{a,c}	6.22^{a,c}	6.31^{a,c}	6.56	± 0.15	133
90	6.95	7.09^{a}	7.52^{a,b}	6.57^{c}	6.52^{c}	6.93	± 0.18	140
120	7.28	7.32	8.06^{a,b}	7.15	7.13	7.39	± 0.17	150
150	7.54	7.74^{b}	8.23^{b}	7.64	7.45	7.72	± 0.14	156
180	7.94	8.30^{b}	8.60^{b}	8.13^{b}	7.88	8.17	± 0.13	166
Average	6.86	6.78	7.15	6.52	6.59	6.78	± 0.11	×
Sx	± 0.35	± 0.45	± 0.51	± 0.48	± 0.37	± 0.43	± 0.19	0.19

Notes: a – significant increase in yield by increasing the nitrogen norm by 30 kg·ha^{-1};
b – significant increase in yield compared to reed canary grass;
c – significant reduction in yield compared to reed canary grass.

From the grasses included in the study, the highest calorific value of the first cut biomass varied from 15.20 MJ·kg^{-1} for tall fescue to 16.90 MJ·kg^{-1} for timothy (Table 2).

The highest calorific values of the biomass of reed canary grass and festulolium did not differ significantly, whereas differences among all other grass species were significant. The smallest biomass calorific values were observed in meadow fescue and tall fescue.

Table 2

Gross calorific value (*Q*) for different grass species, MJ·kg^{-1}

Reed canary grass	Festulolium	Timothy	Meadow fescue	Tall fescue	Average	*Sx*
16.40	16.50	16.90	15.70	15.20	16.14	± 0.30

The sustainability of biomass as an energy carrier is characterized not only by the parameters of the biomass economic properties and quality, but also by its energetic assessment.

The amount of energy from different grasses was directly dependent on their dry matter yield (Figures 1 and 2).

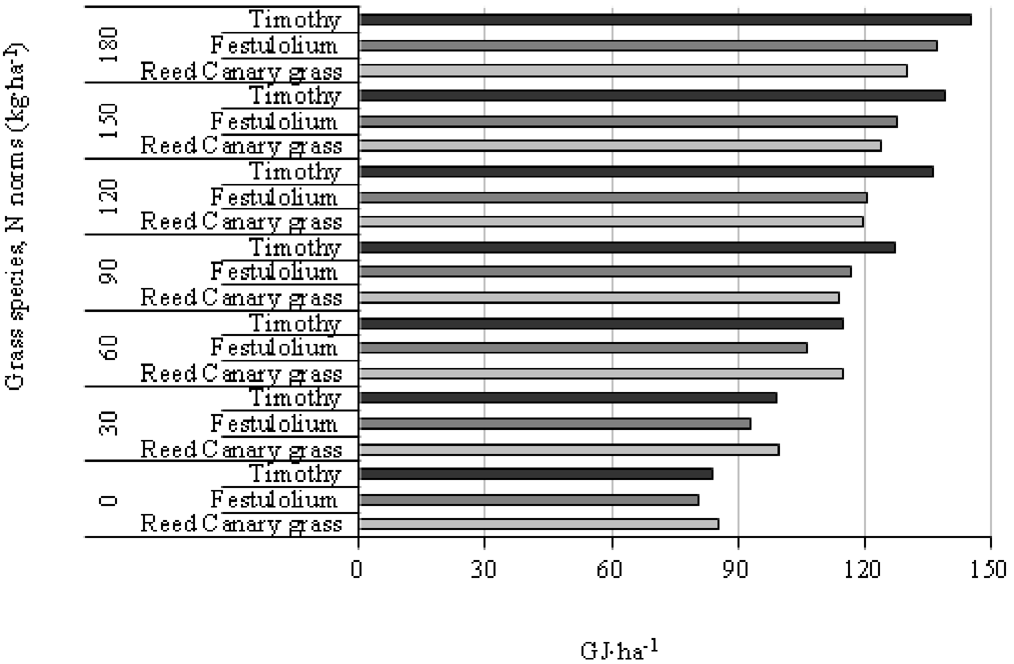

Fig. 1. **Impact of nitrogen fertilizer norms on energy benefit from reed canary grass, festulolium and timothy (average in 2012-2014)**

The amount of energy obtained in the non-nitrogen fertilizer variant with the phosphorus and potassium (P80K120) fertilizer background from 1 ha varied from 71.0 GJ·ha^{-1} for meadow fescue to 85.3 GJ·ha^{-1} for reed canary grass.

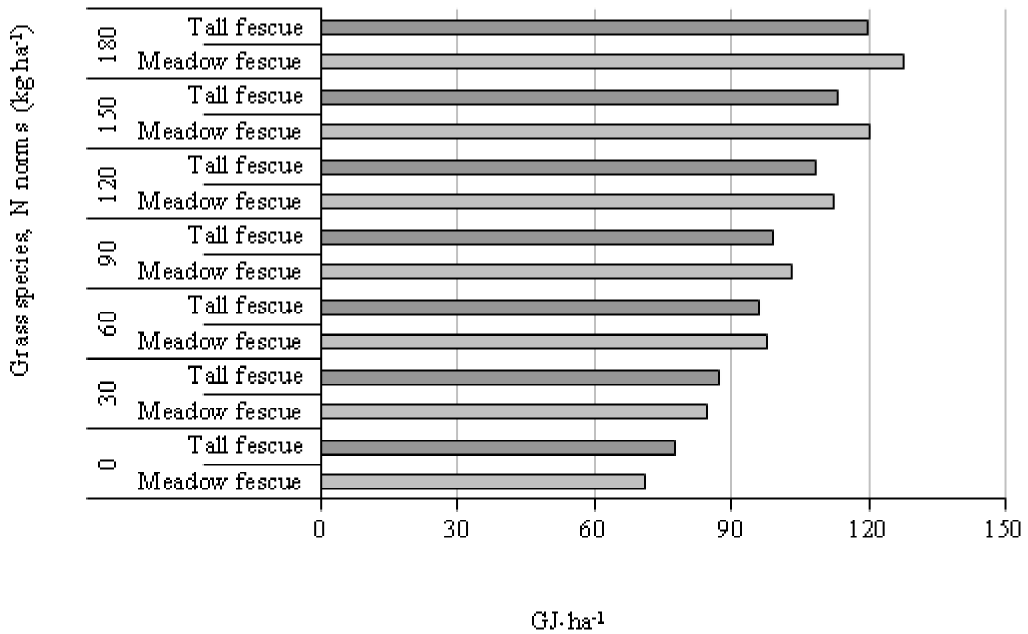

Fig. 2. **Impact of nitrogen fertilizer rates on amount of energy obtained from meadow fescue and tall fescue (average in 2012-2014)**

Nitrogen fertilizers contributed not only to the increase in the dry matter yield, but also to the amount of the energy produced. On average, the amount of energy from 1 ha of all nitrogen standard variants varied from 103.9 GJ·ha^{-1} for tall fescue to 126.9 GJ·ha^{-1} for timothy with respective increase of 34-51 % compared to the non-nitrogen fertilizer variant. The largest amount of energy received from 1 ha was detected in the variant with a nitrogen norm of 180 kg·ha^{-1} N: from 119.8 GJ·ha^{-1} (+54 % compared to the non-nitrogen fertilizer variant) for tall fescue to 145.3 GJ·ha^{-1} for timothy (+73 % compared to non-nitrogen fertilizer).

Conclusions

1. Significant yield increases were obtained using the following nitrogen fertilizer norms: 60 kg·ha^{-1} of N for reed canary grass, meadow fescue and tall fescue, 90 kg·ha^{-1} of N for festulolium, and 120 kg·ha^{-1} of N for timothy.
2. From the first cut, the highest calorific value for grass biomass varied from 15.20 MJ·kg^{-1} for tall fescue to 16.90 MJ·kg^{-1} for timothy. The lowest calorific value was detected for the biomass of meadow fescue and tall fescue.
3. The greatest amount of energy from 1 ha was obtained applying the nitrogen norm of 180 kg·ha^{-1}: 119.8 GJ·ha^{-1} for tall fescue and 145.3 GJ·ha^{-1} for timothy.

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