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Fodder galega (*Galega orientalis* Lam) grass potential as a forage and bioenergy crop

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Abstract Fodder galega (*Galega orientalis* Lam.) is a forage legume that has been grown in Estonia for almost forty five years. Pure galega is known to be persistent, high-yielding crop and rich in nutrients, in particular crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF). Galega is usually grown in a mixture with grass in order to optimize its nutrient concentration, increase dry matter (DM) yield and improve fermentation properties. The trial plots were established on a typical soddy-calcareous soil. There are certain grass species suitable for the mixture. In this study galega mixtures with reed canary grass cv. 'Marathon', timothy cv. 'Tika', red fescue cv. 'Kauni' and festulolium cv. 'Hykor' were under investigation in three successive years (2013–2015). In order to increase competitiveness of grasses and the yield of the first cut, two N fertilization levels were used: N0 and N50 kg ha^{-1}. Two cuts were carried out during the growing season in all three years. The total dry matter yield varied from 9.1 to 12.8 t ha^{-1}. The NDF concentration in the DM varied from 495−559 g kg^{-1}. Both DM-yield and NDF were dependent on the year, mixture, cutting time and fertilization. Nitrogen fertilization (N50 kg ha^{-1}) favoured grass growth and reduced the role of galega in the sward.

Key words: Fodder galega, goat's rue, yielding ability, galega-grass mixtures, fertilization.

INTRODUCTION

In recent decades, renewable energy production has become the focus of energy policy. Increasing the share of renewable energy has been set a target also in EU strategies. For example, Directive 2009/28/EC sets a target of reaching a 20% share of energy from renewable sources in the EU by 2020.

Estonia, like most countries, has ratified the Kyoto Protocol, which requires us to reduce our greenhouse gases emissions. This can only be done by combining different measures: reducing overall energy consumption and using more local energy sources, especially renewable ones.

The most common cultures in warmer climates meant for burning are the plants using the C_4 carbon fixation (Miscanthus, Panicum; Florine et al., 2006). These plants cannot survive low temperatures and soil freezing in northern regions, which is why C_3 carbon fixation reed canary grass is grown in Sweden and Finland (Hadders& Olsson, 1997; Larsson, 2006). Production of biofuels is worth the effort only if it will not cause additional fossil energy consumption. One of the major fossil fuel consumer is the production of mineral fertilizers. The usage of these fertilizers on grasslands reduces compellingly the energy conversion efficiency (MJ MJ^{-1}) of the energyhay (Tonn et al., 2009). Crude oil price is also important aspect for succession.

Organic dry matter yields obtained from galega-grasses mixed swards were higher by 2.3% to 10.7%, compared with pure galega swards at the same soil, fertilization and climate conditions. Average biogas yield per unit of degraded organic matter (DOM) was 533 m^3 Mg_{DOM}^{-1} and average methane yield was 31 m Mg_{DOM}^{-1} (Adamovics et al., 2011).

Different crops have been investigated as raw materials for energy production (Lewandowski et al., 2006; Jasinskas et al., 2008). Most research points out that although harvested yield can be used as energy raw material, economic feasibility of this may be questionable. Using grasses as a source of bioenergy has not been thoroughly studied in Estonia so far. The finnish technology (first cut harvest early in the spring from the frozen soil) is not suitable, because soil will not freeze through on every year and repeated melting periods weakens stems so they lodge (Noormets et al., 2007; Raave et al., 2009). The heat of combustion of grasses and wood are similar but the disadvantage of grasses, compared to wood, is their greater content of potassium and total ash. This complicates using grasses in furnaces as the ash melts at lower temperatures and sticks to the walls of the chamber wherefrom it cannot be easily removed (Hovi, 2006). Preliminary burning tests in a big bale furnace in Nurmiko garden resulted pure galega energy yield 1.6 kWh kg^{-1} (moisture content 16.7%).

Along with other legumes, fodder crops like lucerne and clovers, goat’s rue, i.e. fodder galega have been grown in Estonia for almost forty five years. Galega is very persistent with a high yielding ability. Results have shown that the yields can reach to 10.5 tons of dry matter (1.7 to 1.8 tons of crude protein per hectare) with CP concentration of 200–220 g kg^{-1} DM (Viiralt et al., 1998; Raig et al., 2001; Lillak et al., 2007; Võsa et al., 2008). The nutritive value is the highest when the 1st cut was made at budding or at the beginning of flowering. In order to connect the need for nitrogen fertilizer with biologically bounded nitrogen, it is favourable to grow galega in a mixture with grass.

Of plant nutrients nitrogen has the highest effect on yield and quality of forage crop. When choosing grasses for mixtures, the species development speed, duration and the effect on nutritive value should be considered. Earlier results have shown that growing galega in mixtures with grasses improves the nutritive value and ensiling properties of forage crop (Lättemäe et al., 2005; Meripõld et al., 2014). The total dry matter yields of the three-cut systems varied from 7.6 to 13.7 t ha^{-1}. The CP concentration in the DM varied from 156 to 186 g kg^{-1}. Both DM-yield and CP concentration were dependent on year, mixture and fertilization. A more detailed description of the three-cut system experiment is presented in the article by Meripõld et al. (2016). The aim of the two-cut system investigation was to assess galega and galega-grass mixtures potential as a bioenergy crop.

MATERIALS AND METHODS

The experimental field was established in 2012 in Saku Estonia (local latitude 57° 25'). The study includes a three (2013–2015) years data. The soil type of the experimental area was *Calcaric cambisols* according to the World Reference Base classification (EAO 2014) where the agrochemical indicators were as follows: pH_{KCl} 6.3 (ISO 10390); soil carbon content C_{org} 3.3% (Tyurin method) and concentration of soluble P and K being 114 and 161 mg kg^{-1} (Mehlich III method) respectively. Four galega-grass mixtures were used. The galega cv. 'Gale' (*Go*) was sown in binary mixtures with reed canary grass cv. 'Marathon' (*Pa*) (7 kg ha^{-1}), red fescue cv. 'Kauni' *(Fr*) (10 kg ha^{-1}), timothy cv. 'Tika' (*Pp*) (8 kg ha^{-1}) and festulolium cv. 'Hykor' (*Fe*) (15 kg ha^{-1}) respectively. The sowing rate of the seed of 'Gale' was 15 kg ha^{-1} in all mixtures and pure seeding. A pure fodder galega *(Go)* was included in the trials as a control. The seeds were treated just before seeding with nodule bacteria *Rhizobium galegae.*

In order to increase competitivity of grasses and yield of the first cut, two N fertilization levels were used: N0 and N50 kg ha^{-1} (April or May, depending year conditions). The trials were established in split-plot design in 4 replicates and the size of the harvested plot was 7 m^2. The crop was cut by a scythe MF-70, then weighed and samples were taken for analyses. The botanical composition of crop was determined prior to sampling by comparing the dry matter yield proportion of different species. A two-cut system was used during harvest years and four replicates of the plots of each treatment. The first cut was made after the galega flowering, in the beginning of July. The second cut was made in the beginning of October.

The data determined in this experiment are: dry matter yield (DM), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents. Accumulated effective temperatures over 5 °C for the first cut in 2014 was 241 °C, 2013 291 °C and 2015 year was 178 °C. Effective temperatures of 2015 (Apr–May) were the lowest in the last ten years. The trial results were processed statistically by the method of dispersion analysis (Excel for Windows 2003).

RESULTS AND DISCUSSION

The results indicate that galega-grass mixtures ensured high DM yields since the trial field was established. In the years 2013–2015 the yields varied from 6.6 to 15.5 t ha^{-1} (Table 1). The best DM yield of the three experiment years was obtained from 'Gale'-'Hykor' mixture at N50 fertilizer level.

Table 1. The DM yield (t ha^{-1}) of fodder galega-grass mixtures in 2013–2015

Species	Variety	2013		2014		2015		Average	
		N0	N50	N0	N50	N0	N50	N0	N50
Go	Gale	7.6	7.8	10.0	13.5	10.5.	9.9	9.4	10.4
Go/Pa	Gale/Marathon	8.6	12.1	10.5	15.4	10.6	9.7	9.9	12.4
Go/Pp	Gale/Tika	7.5	8.5	12.8	14.2	8.7	10.5	9.7	11.0
Go/Fr	Gale/Kauni	6.6	8.5	10.6	13.2	10.2	10.9	9.1	10.9
Go/Fl	Gale/Hykor	7.3	11.9	10.9	15.5	9.7	11.0	9.3	12.8
		LSD 0.05 = 1.42		*LSD 0.05 = 2.02*		*LSD 0.05 = 2.2*		*LSD 0.05 = 2.2*	

The yields were higher in 2014 and varying from 13.2. to 15.5 t ha^{-1}. Application of N fertilizer changed the botanical composition of the sward. N fertilizer increased grasses and reduced 'Gale' proportion in the all mixtures. The highest average DM yields of the three experiment years were obtained from 'Gale'-'Hykor' and 'Gale'-'Marathon' mixture supplied with N fertilizer while 'Gale'-'Maraton' and 'Gale'-'Tika' mixtures provided the highest DM yields (9.9 t ha^{-1} and 9.7 t ha^{-1}) without the ferilizer. The yields of two-cut system mixtures were high enough, except 'Gale'-'Hykor' because 'Hykor' is an intensive variety and needs higher N supply during the growth period. The productivity of the 'Gale'-grass mixture is affected by the botanical composition and N fertilization of the mixture. In the N50 variant the yields of 'Gale' pure seeding are generally overcome by the mixtures in the three experiment years.

The ratio of the average (2013–2015) DM yield of the first cut to the average DM yield of the second cut with N fertilizer and without fertilizer was accordingly 1:0.43 and 1:0.48 in case of mixtures and 1:0.51 and 1:0.47 in case of pure 'Gale' (Table 2).

Table 2. The ratio of the first and the second cut (average of 2013–2015)

Variety	Galega	Galega-grass mixtures
N50	1:0.51	1:0.43
N0	1:0.47	1:0.48

In the N fertilizer variant the mixtures exceed pure 'Gale' yield by average in 2013–2015. In the mixtures of 2015, 'Gale' proportions had grown to 66–89%.

In 2013 the average 'Gale' proportion in all mixtures at N50 was 17%, in the second year it was 39% and in the third year were 51%. At fertilization level N0 the red fescue cv. 'Kauni' and festulolium cv. 'Hykor' less competitive (Fig. 1).

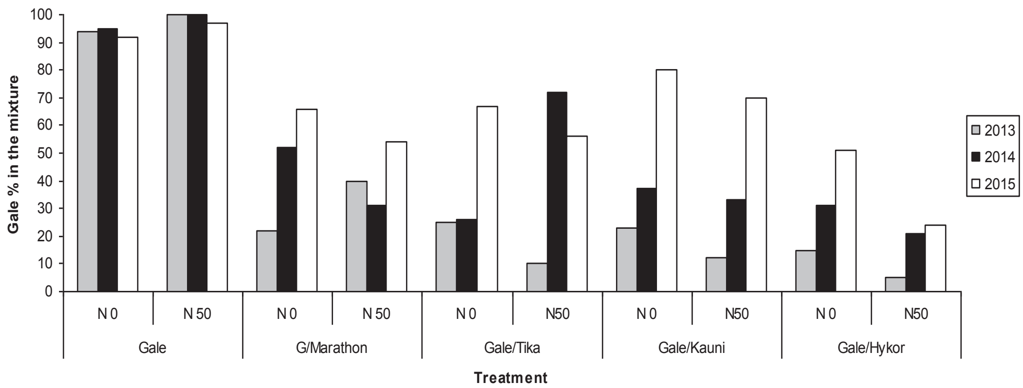

Figure 1. The botanical composition of galega-grass mixture (DM yield) of the first cut in 2013–2015.

In the second cut the highest competitivity was shown by the festulolium cv. 'Hykor' and the reed canary grass cv. 'Marathon' at N50 fertilization level.The red fescue cv. 'Kauni' and timothy cv. 'Tika' were less competitive (Fig. 2).

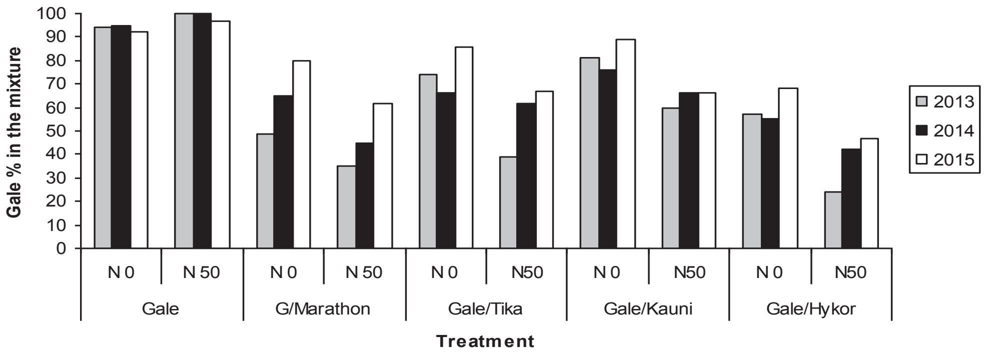

Figure 2. The botanical composition of galega-grass mixture (DM yield) of the second cut in 2013–2015.

The yield of galega harvested at the end of flowering (in the beginning of July) is less valuable, due to the high fiber content. Therefore, it is suitable for baling to produce bioenergy. Earlier results have shown (Meripõld et al., 2016) that growing galega in mixtures with grasses three-cut system improves the nutritive value and ensiling properties of forage crop. In general, the chemical composition of mixtures was mainly dependent on fertilization level and 'Gale' proportion (Table 3). Lower CP concentrations in mixtures (94–105 g kg^{-1} DM) were found in treatments when N fertilizer was not used. The fertilization level N50 increased the CP (100–134 g kg^{-1} DM) concentration. The NDF concentration in the DM varied from 495–554 g kg^{-1}. Both DM yield and NDF were dependent on the year, mixture, cutting time and fertilization. Therefore, the ADF and NDF concentrations were higher in treatments where 'Gale' proportion was higher and in 'Gale'-'Marathon' treatment, obviously due to high fibre concentration of reed canary grass. N50 fertilization favoured grass growth and reduced the role of galega in the sward. As a result of the experiment, it can be concluded that if the first cut was made at the end of flowering period of galega and the second cut in the beginning of October, it is advisable to use the first cut as a bioenergy crop and the second cut as forage.

Table 3. The chemical composition of the fodder galega-grass mixtures of first cut (DM) in 2013–2015

Mixture	Average of 2013–2015			
(Varieties)	N rate, kg ha^{-1}	CP, g kg^{-1}	NDF, g kg^{-1}	ADF, g kg^{-1}
Gale	N0	178	495	439
	N50	170	489	408
Gale/Marathon	N0	99	545	396
	N50	118	553	384
Gale/Tika	N0	96	524	391
	N50	105	544	369
Gale/Kauni	N0	105	541	424
	N50	134	520	387
Gale/Hykor	N0	94	509	392
	N50	100	554	371

'Gale' inclusion in mixtures stabilized summer yields due to the better growth of 'Gale' during summer months.

CONCLUSIONS

The galega-grass mixtures maintained high yielding ability and nutritive value over several years. The chemical composition of mixtures was mainly dependent on fertilization. N fertilization rate 50 kg ha^{-1} favoured grass growth but reduced the role of galega in the sward. On the basis of these results, fertilization rate of N50 should be recommended in order to avoid grasses being lost from the sward and to prevent N deficiency in the spring. The higher yielding ability and similar higher NDF was obtained in 'Gale'-'Hykor' and 'Gale'-'Marathon' mixtures. As a result of the experiment, it can be concluded that if the first cut was made at the end of flowering period of galega and the second cut in the beginning of October, it is advisable to use the first cut as a bioenergy crop and the second cut as forage.

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