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PRODUCTIVITY, PERSISTENCE AND YIELD QUALITY OF GALEGA-GRASS SWARDS

Fodder galega (Galega orientalis Lam.) is a promising, perennial and fast-growing forage legume which is useful for the production of diverse grass forage. Field trials (1986-2003) were carried out with the aim of studying continuous green forage production from fodder galega-grass swards in the stage of intensive growth. The 35 mixed binary and multi – species swards were developed on stagnic luvisol and sod – podzolic and were fertilized with either 0 N or 90 kg N ha $^{-1}$. The swards were composed of fodder galega 'Gale' and thirteen grass species. Swards were cut two to four times during the growing season. Fodder galega in mixtures with grasses of various growth patterns provided continuous green forage production during the whole summer season. The botanical composition and frequency of cutting affected the average productivity of a sward (5.13 to 11.0 t ha $^{-1}$ DM), metabolizable energy (8.32-13.41 MJ kg $^{-1}$ DM) as well as NDF and ADF contents. The swards receiving no fertilizer N were more productive and of high quality.

Key words: *fodder galega, grasses, mixtures, productivity, yield quality*

Fodder galega (*Galega orientalis* Lam.) is an early maturing perennial forage legume, high in productivity and of capacity to fix atmospheric nitrogen (Raig, 1994). Experiments on fodder galega show that this long-lived legume survives in pure stands for 15 to 19 years and provides annual DM yields of 9.56 to 11.0 t ha^{-1} (Adamovich, 2000; Driķis, 1995). Pure fodder galega stands, compared to other legumes, are not thinning out between the years of stand use providing stable yields of green feed and seeds. The use of symbiotic potential of fodder galega grown in mixtures with grasses contributes to the production of ecologically safe forage and animal products.

Materials and technique of investigation. The field trials have been conducted on brown-lessive (pH_{KCl} was 6.7, mobile P − 52, K − 128 mg kg^{-1} of soil) and sod-podzolic gleysolic (pH_{KCl} was 6.2, P − 39, K − 95 mg kg^{-1} of soil) soils in 1986-2003.

All swards were created simultaneously on both types of soil. Binary- and multi-species seed mixtures were composed of fodder galega (*Galega orientalis* Lam.) 'Gale' and grass species: *Alopecurus pratensis, Arrhenatherum elatius, Bromus inermis, Dactylis glomerata*, *Festuca pratensis, Festuca rubra, Festuca arundinacea, Phleum pratense, Lolium perenne, Phalaris arundinacea, Agrostis gigantea, Poa pratensis; Poa palustris*. Field trials on the productivity of fodder galega−grass swards were conducted in three series of experiments, in which 13 binary and 22 multi species mixtures were included. The botanical composition of binary swards, which were cut two times in the growing season, is presented in Table 1. Binary- and multi-species swards for three – and four-fold cutting were as follows: 1. *Galega orientalis (G.),* 2. *G.+Alopecurus pratensis (Al.pr.),* 3. *G.+Dactylis glomerata (D.gl.),* 4. *G.+Lolium perenne (L.per.),* 5. *G.+Poa pratensis (P.pr.),* 6. *G.+Festuca rubra (F.r.),* 7. *G.+Festuca pratensis (F.pr.),* 8. *G.+Phleum pratense (Phl.pr.),* 9. *G.+D.gl.+Al.pr.,* 10. *G.+D.gl.+L.per.,* 11. *G.+D.gl.+F.r.,* 12. *G.+D.gl.+P.pr.,* 13. *G.+D.gl.+F.pr.,* 14. *G.+D.gl.+L.per.+F.r.+P.pr.,* 15. *G.+D.gl.+L.per.+F.r.+P.p.+F.pr.,* 16. *G.+L.per.+F.pr.,* 17. *G.+L.per.+Phl.pr.,* 18. *G.+L.per.+F.r.,* 19. *G.+L.per.+P.pr.,* 20. *G.+L.per.+Phl.pr.+F.pr.,* 21. *G.+L.per.+F.r.+P.pr.,* 22. *G.+L.per.+Phl.pr.+P.pr.,* 23. *G.+L.per.+Phl.pr.+F.pr.+F.r.+P.pr.,* 24. *G.+F.pr.+Phl.pr.,* 25. *G.+F.pr.+F.,* 26. *G.+F.pr.+P.pr.,* 27. *G.+Phl.pr.+F.r.,* 28. *G.+F.pr.+P.pr.+F.r.,* 29. *G.+Phl.pr.+P.pr,* 30. *G.+Phl.pr.+P.pr.+F.r.* The numeration of seed mixtures corresponds to designations (galega + grass) in Figures 1 and 2.

In all experiment series the mixture contained 40 % fodder galega and 60 % grasses. The total seeding rate of each seed mixture was 1000 germinating seeds per m^2. The ratio of fodder galega – grass seeds in mixtures was as follows: 400:600 in binary mixtures, 400:300:300 in three – component mixtures, 400:200:200:200 in four – component mixtures, 400:150:150:150:150 in five – component mixtures and 400:100:100:100:100:100:100 in six – component mixtures. Stands were sown in early May 1986, 1990 and 1997. Trials were arranged in randomised complete blocks in three to four replications. Stands were cut two to four times during the growing season. The plots were fertilised: P 40 and K 150 kg ha^{-1}, and two N-fertiliser treatments N 0, $N\ 90_{(45+45).}$ Chemical composition of plants was determined only on the first cut by the following methods: dry matter (DM) – dried; crude protein (CP) – modified Kjeldahl; crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF)-by van Soest (1980).

Results of research. Productivity of swards. Our studies show that fodder galega, due to a slow growth pattern, provided high green fodder and dry matter yields only in the third to fourth production years. Inclusion of a grass

species in a mixture resulted in yield increases by 26 to 32 % already in the first production year. In 12 production years of pure galega, the following average yields of dry matter and crude protein were attained in early flower: 9.75 t ha^{-1} DM and 1.92 t ha^{-1} CP on stagnic luvisol, and 8.76 t ha^{-1} DM and 1.68 t ha^{-1} CP on sod – podzolic soils. The yields of DM and CP in binary fodder galega – grass swards in different soils depending on mineral N applied at a two-fold cutting regime are presented in Table 1.

1. Productivity of fodder galega in binary mixtures with grasses, t ha^{-1} (1987-1998, 12 years of utilization, two cuts)

Mixtures	Stagnic luvisol				Gleyic podzol			
	N0		$N90_{(45+45)}$		N0		$N90_{(45+45)}$	
	DM yield	CP yield	DM yield	CP yield	DM yield	CP yield	DM yield	CP yield
Galega orientalis	9.47	1.84	10.03	2.01	8.60	1.57	8.92	1.79
Gal.+Alopecurus pratensis	10.13	1.77	11.35	1.91	9.04	1.56	10.15	1.67
Gal.+Dactylis glomerata	10.92	1.70	11.62	1.74	9.80	1.57	11.74	1.81
Gal.+Arrhenatherum elatius	11.29	1.94	12.84	2.17	12.34	2.12	11.56	1.92
Gal.+Phalaris arundinacea	8.84	1.41	9.10	1.38	8.30	1.27	10.64	1.61
Gal.+Festuca pratensis	10.03	1.71	11.15	1.87	8.76	1.47	10.49	1.68
Gal.+Festuca arundinacea	12.78	1.99	13.02	1.82	11.26	1.68	12.75	1.81
Gal.+Bromus inermis	11.05	1.56	12.32	1.63	9.75	1.40	11.80	1.62
Gal.+Phleum pratense	10.87	1.84	11.59	1.85	9.76	1.58	12.30	1.94
Gal.+Poa pratensis	7.36	1.20	8.71	1.31	8.19	1.32	9.07	1.44
Gal.+Festuca rubra	8.78	1.35	9.97	1.51	8.40	1.28	9.23	1.38
Gal.+Agrostis alba	8.30	1.25	9.11	1.42	7.15	1.14	8.14	1.36
Gal.+Poa palustris	8.83	1.38	9.94	1.53	9.15	1.51	9.80	1.64
Gal.+Lolium perenne *	11.45	2.01	12.68	2.03	9.76	1.67	11.88	1.90
Averages in binary mixtures	10.05	1.62	11.03	1.71	9.36	1.51	10.73	1.68
$LSD_{0,05}$	0.68	0.14	0.77	0.17	0.43	0.15	0.59	0.11

[1] N applied at 0 kg ha^{-1}. The N90 was split in two equal applications.
[2] Seven – years average

The development of dense and highly productive swards was observed earlier on light textured soils, compared to heavy textured soils. The productivity of binary fodder galega-grass swards was the following: the average yield 9.71 t ha^{-1} DM in swards receiving no fertiliser N, and 10.88 t ha^{-1} DM in swards splitting the fertiliser into two applications − at the beginning of the growing

season and after cut 1. Fodder galega-grass swards contributed to the crop yield and made N available for the benefit of companion grasses.

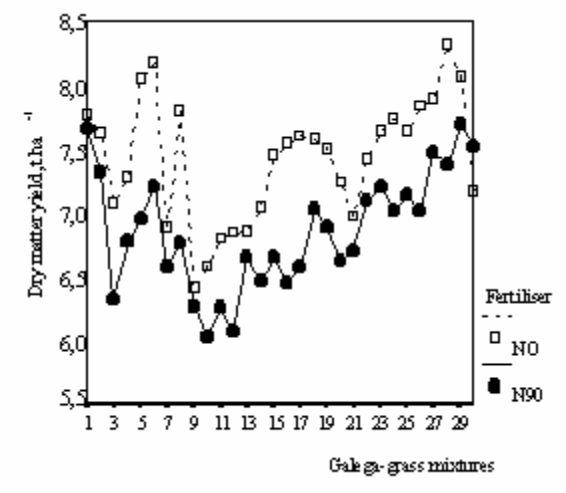

Fig. 1. ***Productivity of fodder galega-grass swards depending on nitrogen fertiliser (average 1998-2000)***

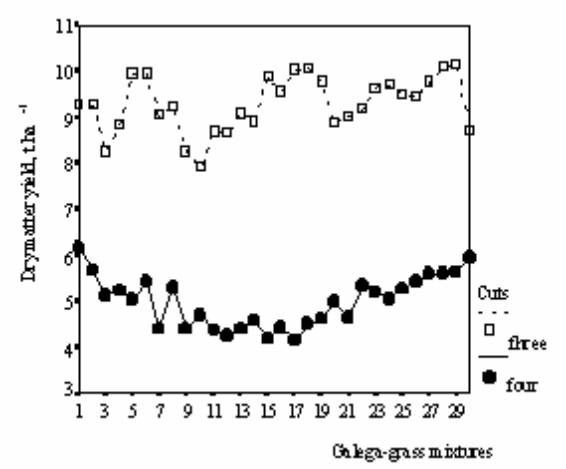

Fig. 2. ***Productivity of fodder galega-grass swards depending on the frequency of cutting (average 1998-2000)***

Under conditions of increased cutting treatments in 5 production years in pure galega stands the following average yields of DM and CP protein were attained in the bud stage: 9.23 t ha^{-1} DM and 1.90 t ha^{-1} CP by three – fold cutting during growing season, and 7.13 t ha^{-1} DM and 1.47 t ha^{-1} CP at four – fold cutting treatments, respectively.

Essential (P>95%) changes were observed in the productivity of galega-grass swards in all treatments, depending on N-fertilizer and frequency of cutting (Fig.1. and 2.).

Receiving no fertilizer N, highly productive binary and three species galega-grass swards were developed providing the following average yields of DM and CP: 9.16 t ha^{-1} DM and 1.80 t ha^{-1} CP at three-fold cutting treatments and 6.34 t ha^{-1} DM and 1.47 t ha^{-1} CP at four-fold cutting regime.

The average DM yields, obtained from thirty swards differing by the number of components in a sward and the number of mixtures in each group, are presented in Table 2.

2. Dry matter yields of fodder galega/grass swards, t ha^{-1} (1998-2003, five production years on average)

Regime of cutting (F_A)	Nietrogen fertilizer, kg ha^{-1} (F_B)	Composition of swards (F_C)						Average	Average (F_A)	Average (F_B)
		fodder galega	number of components in mixtures							
			two	three	four	five	six			
Three – fold	N 0	9,26	9,69	10,15	9,94	9,98	10,07	9,97	9,16	8,16
	N 90	8,43	8,46	8,01	8,26	8,45	9,23	8,48		7,26
Four – fold	N 0	7,13	6,73	6,19	6,64	6,15	6,08	6,36	6,34	
	N 90	6,90	6,11	5,77	6,35	5,80	6,19	6,04		
Average (F_C)		7,93	7,75	7,53	7,80	7,60	7,89	7,71		
$LSD_{0.05}$ F_A = 0.04; F_B = 0.04; F_C = 0.17; F_{AB}=0.06; F_{AC}=0.24; F_{BC}=0.24										

Depending on the cutting regime, highly productive binary swards were developed when growing fodder galega in association with *Arrhenatherum elatius, Dactylis glomerata*, *Festuca arundinacea, Phleum pratense, Lolium perenne, Festuca rubra and Poa pratensis*. Most productive fodder galega – grass mixtures were composed of three species providing the following average yields: 10.05−12.36 t ha^{-1} DM and 1.98−2.34 t ha^{-1} CP, where particularly excelled the following three species mixed swards: *Galega orientalis* 40%+ *Arrhenatherum elatius* 30%+ *Festuca arundinacea* 30%, *Galega orientalis* 40%+ *Arrhenatherum elatius* 30%+ *Dactylis glomerata* 30%, and *Galega orientalis* 40% + *Phleum pratense* 30% + *Lolium perenne* 30% providing the highest yields of DM − 14.23, 13.75 and 13.06 t ha^{-1} respectively. At three-fold cutting regime, three-component mixed swards excelled with CP and DM yields

providing 1.86 and 10.15 t ha $^{-1}$, respectively. The most productive were the following three species mixed swards: *Galega orientalis* 40% + *Lolium perenne* 30% + *Phleum pratense* 30%*; Galega orientalis* 40% + *Lolium perenne* 30% + *Festuca rubra* 30%; *Galega orientalis* 40% + *Phleum pratense* 30% + *Poa pratensis* 30%; *Galega orientalis* 40% + *Phleum pratense* 30% + *Festuca rubra* 30%, providing the highest yields of DM − 11.06, 10.87, 10.86 and 10.51 t ha^{-1} respectively.

The crop yield level in a sward was not significantly effected by the increase of the number of the species from 4 to 6 in a sward, compared to binary and three species mixed swards, but it ensured, stability of yields between production years.

Dynamics of the botanical composition of swards. The proportion of grass components in the determination of sward productivity was greatly dependent on cenotic activity and competition ability of plant species. In the first production years the companion grasses, such as *Dactylis glomerata, Festuca arundinacea, Lolium perenne,* contributed to the total yield of the sward. The proportion of creeping grasses, such as *Alopecurus pratensis, Bromus inermis*, *Phalaris arundinacea, Agrostis alba, Festuca rubra, Poa pratensis*, increased beginning with 3rd, 4th and 5th production years. The rapid increase of the creeping grasses was observed on light sod – podzolic soils. The proportion of grasses in mixed stands accounted for 32.4-46.2% on average, in the 1st cut in treatments receiving no fertilizer N. Application of fertilizer N resulted in the increase of grass species in swards 44.3 to 61.8 % and had a declining effect on the competition ability of fodder galega. Fodder galega was always the dominating plant species in cut 2 and cut 3. Inclusion of most competitive grasses, such as cocksfoot, meadow foxtail, tall or false oat grass, upright brome, perennial ryegrass as well as intensive cutting treatments essentially affected survival of fodder galega in mixed swards as well as the productive longevity of these swards.

Yield quality. The chemical composition of plants and the ratio of fodder galega to grasses were studied. In branching and bud stages, fodder galega excelled with high crude protein contents, 306 ± 23 g kg^{-1} DM, particularly high protein content – 385 g kg $^{-1}$ DM was observed in plant leaves. In mixed swards the CP content in fodder galega declined down to 262 ± 11 g kg^{-1} DM in the bud stage in early flower the average CP content was 208 ± 25 g kg^{-1} DM.

This could be explained by the great proportion of plant leaves accounting for 581 ± 39 g kg^{-1} DM in the legume yield. The fixed atmospheric nitrogen fully met the demands necessary for the development of fodder galega and contributed to the growth of associate grasses in a sward in treatments receiving

no mineral fertiliser N. Fodder galega promoted the increase of N content in the companion grasses by 3 to 5 g kg^{-1} (CP content 19 to 31 g kg^{-1} DM), on average, compared to pure grass stands.

Split application of the fertilizer N 90 negatively effected the proportion of galega in a sward resulting in the decrease of DM yields by 1.49 t ha^{-1} at three-fold cutting treatments, compared to unfertilized plots. Frequent, four-fold cutting treatments had a declining effect on the productivity of galega-grass mixtures. The total yield of DM decreased by 2.82 t ha^{-1} or 30.8% in all experimental plots at four-cutting treatments.

In branching and bud stages fodder galega excelled with high crude protein contents, 295 ± 18 g kg^{-1} DM. In mixed swards the CP content in fodder galega declined down to 276 ± 19 g kg^{-1} DM in the bud stage; in early flower the average CP content was 206 ± 31 g kg^{-1} DM. This could be explained by the great proportion of plant leaves accounting for 549 ± 57 g kg^{-1} DM in the fodder galega yield. The fixed atmospheric nitrogen fully met the demands necessary for the development of fodder galega and contributed to the growth of associate grasses in a sward in treatments receiving no mineral fertiliser N. The average content of metabolizable energy was 13.0 MJ kg^{-1} DM of fodder galega, in mixed galega – grass stands it was 12.6 ± 1.1 MJ kg^{-1} DM (Table 3).

3. Yield quality of fodder galega/grass swards (1998-2000, three production years, cut 1 and cut 2 on average)

Regime of cutting	Index of quality	Composition of swards						Average in mixtures
		fodder galega	number of species in mixtures					
			two	three	four	five	six	
Three-fold	galega in DM yield, g kg^{-1}	912,0	483,4	472,0	473,3	400,5	430,0	451,8
	ME, MJ kg^{-1} DM	10,8	10,7	11,0	11,6	10,4	11,0	10,9
	NDF, g kg^{-1} DM	409,5	405,7	397,8	417,9	443,0	413,3	415,5
Four-fold	galega in DM yield, g kg^{-1}	888,5	378,5	325,7	411,7	346,5	327,8	358,0
	ME, MJ kg^{-1} DM	11,1	12,0	12,1	12,7	11,9	13,6	12,5
	NDF, g kg^{-1} DM	379,0	364,4	365,5	367,3	390,0	376,5	372,7

Literature findings (Driķis, 1995; Moller, Hostrup, 1996) indicate that there is a rapid increase of the CF content, including NDF and ADF fractions when cutting fodder galega in early flower and later. Our studies showed that in mixtures with grasses the average NDF content did not exceed 382 ± 24 g kg^{-1} DM, compared to NDF content 422 ± 38 g kg^{-1} DM in pure galega stands in early flower. This could be explained by the different proportion of plant leaves and their position in canopy structure in galega-grass mixtures, compared to pure galega swards. The slower growth pattern of associate grasses in a mixed

sward resulted in slower maturation and age of grass leaves, compared to galega, thus contributing to a qualitative forage production.

From the obtained research results it can be concluded that fodder galega in pure stands or in mixtures with grasses of various growth patterns was productive, of high quality and persisted for long periods, but three species mixtures were most productive. Galega in pure or mixed stands with fixed sufficient amounts of N eliminated the need for N-application.

Conclusions. Fodder galega in pure stands or in mixtures with grasses of various growth patterns is productive, of high quality and persists for long periods, but three species mixtures proved to be most productive. Competitive grasses in the mixtures reduce productive longevity of swards compared to pure galega stands. Galega in pure or mixed stands fixes sufficient amounts of N, thus eliminating the need for N-application.

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