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Forage grass productivity and quality in south-western part of Pannonian basin

Produktivnost i kvaliteta krmnih trava u jugozapadnom dijelu Panonske nizine

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Abstract

The aim of the research was to compare the productivity and quality of several forage grasses in the climate conditions of south-eastern Europe. The research was conducted during 2012 and 2013, in the south-western part of the Pannonian basin (vicinity of Osijek, Croatia). The experiment included 5 grass species: Italian ryegrass (*Lolium multiflorum),* cocksfoot (*Dactylis glomerata)*, hybrid ryegrass (*Lolium x boucheanum),* perennial ryegrass (*Lolium perenne)* and timothy (*Phleum pratense*) cut three times per year, i.e. 6 cuttings in total for two years. The results have shown that there were significant statistical differences for all investigated traits between the years of the species and their interaction at the $P<0.05$ levels. In average, the highest dry matter yield was achieved during the first year of usage (10.4 and 9.1 t/ha). The average usage of two years, the highest yields of dry matter had Italian ryegrass and cocksfoot. Quality results showed that the cocksfoot was the least digestible because it contained over 700 g/kg of neutral detergent fiber (NDF) and 450 g/kg of acid detergent fiber (ADF), unlike the perennial ryegrass which had 559 and 327 g/kg of NDF and ADF. Energetically most productive was Italian ryegrass with a production potential of 19,739 liters of milk and with milk fat of 4%. On the protein productivity base, the most prominent was the cocksfoot which could produce 11,878 liters of milk from 713 kg proteins in one year. The results show that none of the tested grasses had a balanced relationship between protein and energy.

Keywords: digestibility, grasses, NEL, quality, yield

Sažetak

Istraživanje je imalo za cilj komparirati produktivnost i kvalitetu nekoliko vrsta trava u klimatskim uvjetima jugoistočne Europe. Istraživanje je provedeno tijekom 2012. i 2013. godine u jugozapadnom dijelu Panonske nizine (okolica Osijeka, Hrvatska). U pokusu su istraživani klupčasta oštrica, mačji repak, talijanski, hibridni i engleski ljulj u 4 repeticije. Provedene su 3 košnje po godini ili 6 otkosa za svaku vrstu tijekom pokusa. Rezultati su pokazali da postoje značajne statističke razlike za sva istraživana svojstva između vrsta, godina i njihove interakcije na nivou P<0,05. U prosjeku, najveći prinos suhe tvari ostvaren je tijekom prve godine uporabe (10,4 i 9,1 t/ha). U prosjeku za dvije godine korištenja, najveći prinosi suhe tvari imali su talijanski ljulj i klupčasta oštrica. Rezultati kvalitete pokazali su da je klupčasta oštrica bila najmanje probavljiva, jer je sadržavala preko 700 g/kg vlakna topiva u neutralnom detrđentu (NDF) i 450 g/kg vlakna topiva u kiselom detrđentu (ADF), za razliku od engleskog ljulja koji je imao 559 i 327 g/kg NDF i ADF. Energetski najproduktivniji je bio talijanski ljulj sa proizvodnim potencijalom od 19.739 litara mlijeka uz mliječnu mast od 4%. Na osnovu proteina najprinosnija je bila klupčasta oštrica, koja može proizvesti 11.878 litara mlijeka iz 713 kg proteina u jednoj godini. Rezultati pokazuju da niti jedna testirana trava nije imala balansiran odnos proteina i energije.

Ključne riječi: kvaliteta, NEL, prinos, probavljivost, trave

Introduction

Hay of perennial grasses and legumes is the primary source of valuable forage for feeding dairy cows. Perennial grasses, unlike legumes, are less sensitive to soil acidity, they are more tolerant to diseases and insect attacks (Leto et al., 2006; Nie and Norton, 2009). Dry and high summer temperatures reduce the number of cuts and increase the risk of production (Tucak et al., 2016; Falasca et al., 2017). Therefore, it is necessary to systematically collect information about the adaptability of forage grasses for each climate location within each region (Romani et al., 2002; Chapman et al., 2008). The productivity of hay and grass species in dry conditions of south-western Pannonian basin (during summer) is not satisfactory for intensive milk production, neither the quality and nor the quantity. Therefore, the choice of adaptable grass, species and cultivars is very important. Knowing reaction to the agro-ecological conditions, which are results from the combined effects of environmental factors such as type of soil, water availability, climate, altitude (Buxton and Readfearn, 1997; Todorova et al., 2002; Sokolovic et al., 2011) are very important in management practices (Duru et al., 2009; Gaujournd et al., 2012). Animal performance mainly depends on the quality of forage available to livestock (Glover et al., 2004; Lazzarini et al., 2009), therefore, a basic precondition for obtaining hay quality is timely mowing in the heading stage, because it gets a satisfactory leaf/stem ratio (Duru et al., 2008; Čop et al., 2009). Optimal developmental stage for grass mowing is inflorescence emergence stage, when the proportion of dry matter (DM) in plants is 15 to 20% (Vranic et al., 2009). With aging, i.e. delaying of mowing, proportion of dry matter in plant rises, so growing in the

inflorescence emerged stage, grasses have 20-30% DM and in a thesis stage 30-50% DM, while in soft dough stage proportion of DM can be over 50%, but significantly reduces the quality (Cherney et al., 1993).

A large number of grass species differs in the quality of feed, depending on the age of the crop, usage, purpose of cultivars, abiotic and biotic effects. For this reason, it is important to determine the nutritional value of forage in livestock nutrition, because effective livestock production is related to the amount of nutrients in the forage (Schut et al., 2010). The most common parameters used to determine the quality and nutritional value of the forage are: the crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), total digestible nutrients (TDN), metabolic energy (ME) and net energy of lactation (NEL) (White and Wight, 1984; Pinkerton, 2005). Grass species differ in the proportion of soluble fiber in acid detergent. Grasses with less ADF have greater potential in the diet and are generally better than species with more ADF (Weiss, 1998).

Degradability of crude protein in forage has been influenced by number of factors such as: species, the maturity stage and interaction between crops and environment. The maturity stage affects the degree of degradation NDF in the rumen. The aim of this research is to compare the productivity, nutritive value and the quality of hay in different grass species and to asses' potential in the milk production.

Material and methods

The experiment was established 20 September 2011, on luvisol soil type (Table 1) at Croatian Centre for Agriculture, Food and Rural Affairs in North-eastern Croatia (45°52' north latitude, 18°68' east longitude), at 98 m above sea level. According to the climatic characteristics the area is classified as semi humid. During the two years (2012-2013) through six cuts were analyzed yield and quality of five most commonly used forage grasses: Italian ryegrass (*Lolium multiflorum* Lam. cv. Tetraflorum), cocksfoot (*Dactylis glomerata* L. cv. Amba), hybrid ryegrass (*Lolium x boucheanum* Kunth. cv. Bilbo), perennial ryegrass (*Lolium perenne* L. cv. Naki) and timothy (*Phleum pratense* L. cv. Boxer).

Table 1. Chemical characteristics of luvisol

Profile	pH		Organic matter	Nitrogen (mg/kg)		AL (mg/100 g)	
	KCl	H_2O	%	NO_3	NH_4	P_2O_5	K_2O
0-30 cm	5.4	6	1.7	4.4	1.5	35.7	33.2

A randomized block design was used to assess species effects with four replications and plot size was 8 x 1.25 m. The plots were fertilized with 79 kg N: 100 kg P_2O_5: 150 kg K_2O per hectare in autumn. Spring application was carried out with 40 kg N per hectare every year.

Dry matter samples were taken from each plot per cut, harvesting and weighing biomass in inflorescence emerged stage. In order to use uniform developmental phases of different grass species, samples from the second cut each year for chemical analysis were taken. Crude protein (CP), soluble fibers in neutral detergent (NDF) and soluble fibers in acid detergent (ADF) to the standard methods (Van Soest et al., 1991; Cunniff and AOAC International, 1995) were analyzed. Based on the chemical composition total digestibility index (TDI), the net energy content of lactation (NEL), metabolic energy (ME) and digestible proteins (DP) were calculated. The calculation of NEL and DP were done on DLG (1997) system for productive needs of dairy cows for 1 L of milk with 4% of milk fat.

Differences among grasses were tested using analysis of variance with SAS – PROC GLM procedure by SAS 9.4 (SAS Institute, 2013). Least significant difference (LSD) at 5% significance level was used for comparison of means. The following model was used for combined analysis: $Y_{ijk} = \mu + Y_j + B_k + (YB)_{kj} + S_i + (SY)_{ij} + e_{ijk}$; where Y_{ijk} = measured response of species i in block k of year j; μ = grand mean; S_i = effect of species i; Y_j = effect of year j; SY= species by year interaction; B_k = effect of block k; $(YB)_{kj}$= year j by block k interaction; e_{ijk} = random error effect of species i in block k of year j. For each year analysis, the model was: $Y_{ik} = \mu + S_i + B_k + e_{ik}$; where Y_{ik} = measured response of species i in block k; μ = grand mean; S_i = effect of species i; B_k = effect of block k; e_{ik} = random error effect of genotype i in block k.

Due to climatic conditions, the experimental site is representative of the southern part of the Pannonian region, which is situated in south-eastern Europe (Figure 1). Meteorological data were obtained from the national meteorological station in Osijek. Average rainfall according to the 30 year records for that location is 683 mm with an average air temperature of 11.3 °C. According to Lang's climate classification, the location where experiment was conducted alternated at the semi-arid and semi-humid climate. The average rainfall during vegetation in 2012 and 2013 was unequally distributed over the vegetation cycle. In 2012 precipitations were uniform and minimal during all months, while in 2013 there were long drought period during July and August and rainfall extremes in May and September (Figure 1).

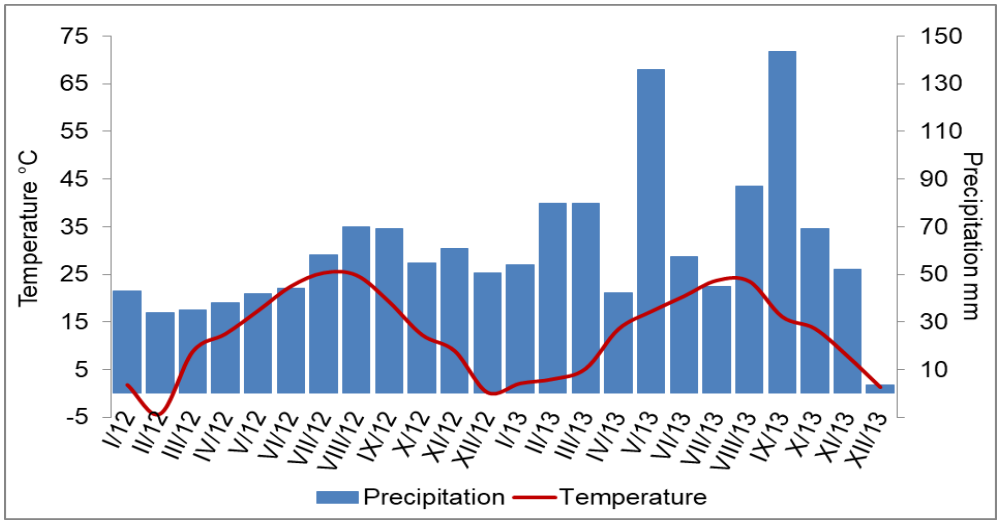

Figure 1. Climatic conditions during two years of experimental on the location Osijek

Results and discussion

The combined analysis of variance over years showed significant differences among the tested species and years and their interactions for all traits at level P<0.05. The productive potential of a species is the result of its interaction with the environment. Environmental factors such as soil, moisture and temperature over years have an impact on yield performance.

There is strong influence of environmental factors during various stages of crop growth (Smeal et al., 2005), thus species differ widely in their response to environments. Some species exhibit highly specific response to an environment (rainfall and temperature), others are even in the performance over a range of environments. On average of two years use, the highest yield of dry matter was achieved by Italian ryegrass and cocksfoot, while timothy and perennial ryegrass achieved the lowest yield in two years (Table 2). It is determined that the cocksfoot has a much higher yield in the second year than all other species. Realized values are closely related to its growth and developmental physiology with a long-life span, deep root and a strong tolerance to cutting (Stjepanović et al., 2008; Andreata-Koren et al., 2009).

Table 2. Dry matter yield (t/ha) and crude protein (g/kg) by species and years

Species	Dry matter yield (t/ha)			Crude Protein (g/kg)		
	2012	2013	Mean	2012	2013	Mean
Cocksfoot	10	12.9	11.4	11.14	6.94	9.04
Timothy	6.2	9.3	7.8	11.32	9.53	10.42
Hybrid ryegrass	12.9	7.4	10.2	8.63	7.16	7.89
Perennial ryegrass	8.8	6.5	7.7	11.84	8.76	10.3
Italian ryegrass	13.9	9.4	11.7	7.17	6.66	6.92
Total	10.4	9.1	9.7	10.02	7.81	8.91
$LSD_{0.05}$-Year (Y)	0.8			0.02		
$LSD_{0.05}$-YxS	1.1			0.04		
$LSD_{0.05}$-Species (S)			0.9			0.04

All components included in the composition of dry matter and protein content were differed between grasses at P<0.05 level. In average of two years, timothy achieved highest dry matter and protein content (Figure 2, Table 2). The lowest proportion of crude protein had hybrid ryegrass. The values of the crude protein that was analyzed

were lower than the values according to DLG values. Similar values of protein content achieved Sokolović et al. (2006) in perennial ryegrass grown in similar environmental conditions. The achieved results for the proteins disagree with the results and comparative researches of Fairey (1985) and Wilman et al. (1996), which stated that the Italian ryegrass and perennial ryegrass had a superior forage quality compared to other grass species. A lower proportion of crude protein content in hybrid ryegrass and Italian ryegrass indicated that these species are susceptible on long dry period.

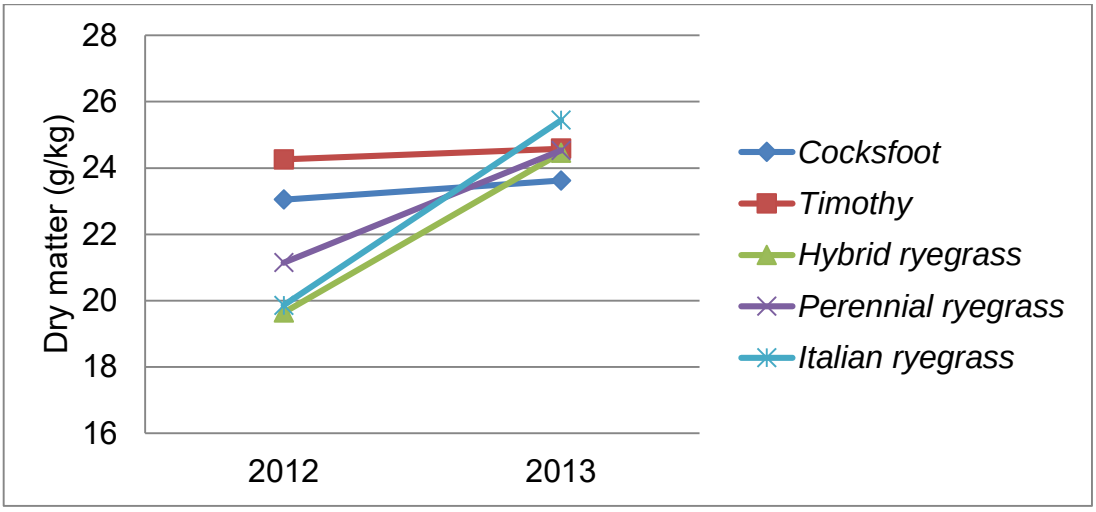

Figure 2. Dry matter content per years

The significant (P<0.05) differences for NDF and ADF contents of grasses are indicated in Figure 3. The result has revealed that the highest NDF and ADF contents recorded for all tested grasses, indicating low quality grasses when compared with other studies (Chapman et al., 2008; Ragnarsson and Linberg, 2008; Gallo et al., 2013). Givens et al. (1993) also reported that grasses had the highest NDF and ADF contents when growing in unfavorable conditions. All included grasses had NDF content higher than critical level (500 g/kg DM) which Paulson et al. (2008) states as a quality limit. The reported NDF values for *Dactylis* and *Phleum* were much higher than the threshold level (higher than 600 g/kg DM). All three *Lolium* species had better quality and digestibility, but not on the level which were expected.

All investigated grasses had statistically significant differences in the level of P<0.05 for the nutritional value of ME (metabolic energy), NEL (net energy of lactation) and DP (digestible protein). Metabolic energy (ME) is the portion of gross energy that is useful for metabolism. It is the thing that is left after accounting for energy in feces, urine and gasses and it is still not all available for an animal to use (Mlay et al., 2006). Estimates of ME in feeds can be done either directly by measuring *in vivo* digestibility, which is expensive, time consuming and laborious. The easiest way is to calculate the energy content from chemical composition and digestibility data, as it was done in this study.

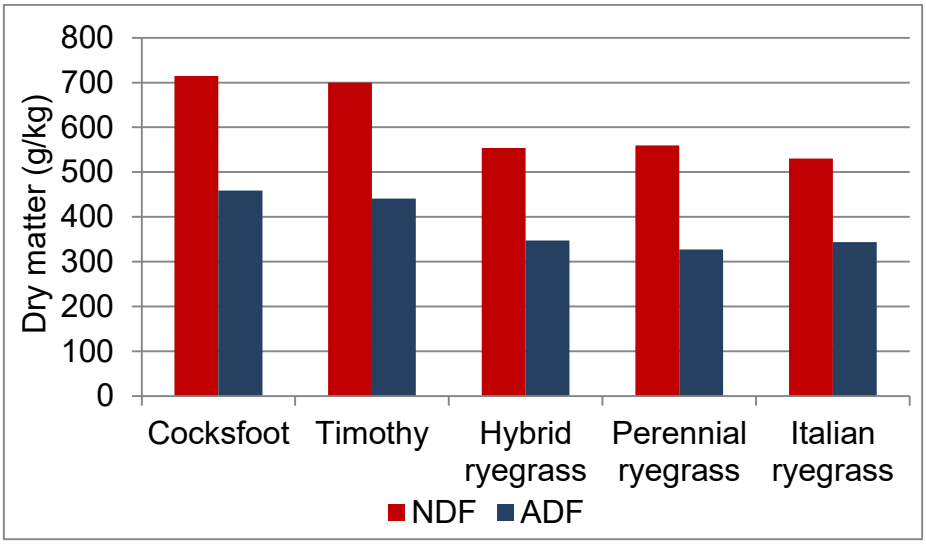

Figure 3. The average content of NDF and ADF (g/kg DM) during two years

The highest metabolic energy (9.44 MJ/kg DM) was detected in Italian ryegrass and the lowest in cocksfoot (7.67 MJ/kg DM) and timothy (7.69 MJ/kg DM). ME values obtained in this study for grasses were lower than in other studies (Givens et al., 1993), but within the range of values reported by Mlay et al. (2006), for grass mixture (6.78 MJ/kg DM). In two of the five grasses (cocksfoot and timothy) were not evidenced a minimal energy concentration between 5 and 6 MJ per kg DM which is a good base for milk production from grasses (Table 3).

Table 3. The content of ME (MJ/kg DM) and NEL (MJ/kg DM) by species and years

Species	ME MJ/kg DM			NEL MJ/kg DM		
	2012	2013	Mean	2012	2013	Mean
Cocksfoot	7.42	7.92	7.67	4.67	4.44	4.56
Timothy	7.38	8.01	7.69	4.66	4.84	4.75
Hybrid ryegrass	9.21	9.23	9.22	5.5	5.29	5.4
Perennial ryegrass	8.6	9.45	9.03	5.61	5.67	5.64
Italian ryegrass	9.11	9.77	9.44	5.22	5.56	5.39
Total	8.35	8.87	8.61	5.13	5.16	5.15
$LSD_{0.05}$-Year (Y)	0.02			0.01		
$LSD_{0.05}$- YxS	0.03			0.02		
$LSD_{0.05}$-Species (S)			0.02			0.01

Average values for NEL show that Italian ryegrass is the energetically most valuable grass in this study. Comparing energy production per years, all species had higher energy production in first year except cocksfoot which had more valuable energy in second year. Contrary, for digestible protein the largest proportion has been determinated for cocksfoot and the smallest one in timothy (Table 4).

Table 4. The total productivity of NEL (GJ/ha) and DP (kg/ha) by species and years

Species	NEL (GJ/ha)			DP (kg/ha)		
	2012	2013	Mean	2012	2013	Mean
Cocksfoot	46.6	57.3	52	790	636	713
Timothy	29	45.1	37	500	631	565
Hybrid ryegrass	71.2	39.1	55.2	793	375	584
Perennial ryegrass	49.4	36.9	43.1	741	404	572
Italian ryegrass	72.7	52.5	62.6	709	446	578
Total	53.8	46.2	50	706	498	602
$LSD_{0.05}$-Year (Y)	3.7			53		
$LSD_{0.05}$- YxS	5			60		
$LSD_{0.05}$-Species (S)			3.6			43

The estimated energy productivity in milk per unit area of the studied grasses (Figure 4) justified significant difference at $P<0.05$ between species. On the average, the most of energy was produced by hay of Italian ryegrass, whose energy can produce 19,739 liters of milk with 4% fat per year. The largest productivity of digestive protein per hectare had cocksfoot (713 kg/ha) which is enough for producing 11,878 liters of milk with 4% fat. The result of this study clearly indicates of non-balancing ratio of energy and protein in all examined grasses. Therefore, these unbalanced energy and protein ratio reducing in the productivity of milk. These values are the results of intolerance on high temperatures in the summer months which influences quick passing through developmental stages. Therefore, imposes the need to combine several different grasses with perennial legumes for better balance and better productivity in dry summer months.

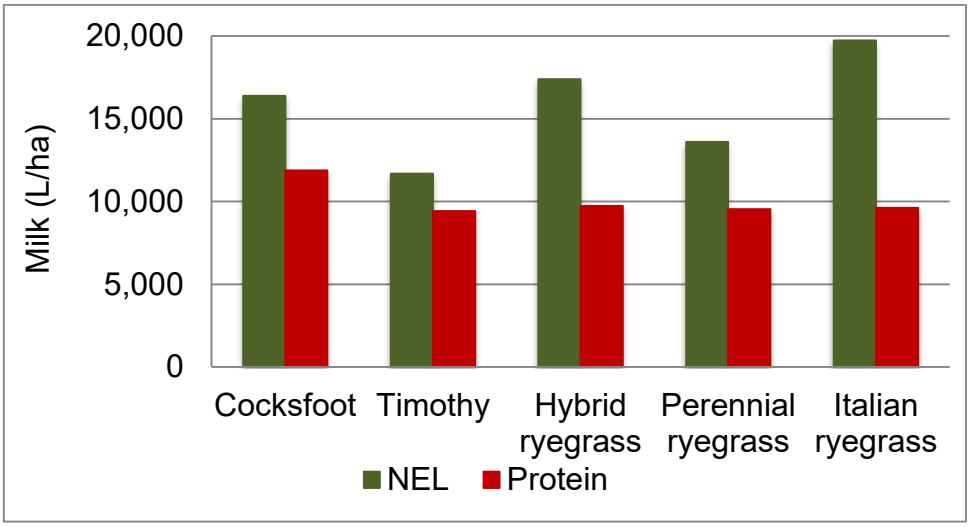

Figure 4. The average productivity of NEL (L milk/ha) and DP (L milk/ha) by species

Conclusions

In the presented study productive and quality gradients of five forage grasses in the south-western part of the Pannonian basin are assessed. They were exposed to stress conditions in summer season, especially high temperatures and drought period suppressed grass growth. The highest yield produced Italian ryegrass, but protein content per hectare and highest energy value showed cocksfoot and Italian ryegrass. In general, it can be concluded that more balanced and better exploited grassland would be sown by grass mixture in those environmental conditions in combination with drought tolerant legume – alfalfa.

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