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Effects of nitrogen and harvesting time on chemical composition of biomass of Sudan grass, fodder sorghum, and their hybrid

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Abstract: The subject of this study is 2-year variability research (2007 and 2008) of the chemical composition of naturally dried biomass samples of 3 different sorghum species, which are widely used in the southeast Balkans. Samples of Sudan grass Zora, fodder sorghum NS-Dzin, and their hybrid Siloking were examined based on the quantity of used nitrogen and the harvest time. Plants were grown in the experimental field of Radmilovac (property of the Faculty of Agriculture in Belgrade) in a randomized block, split-split plot design with 3 replications for 2 years. Naturally dried biomass with the highest amount of total proteins was obtained by mowing during the stem elongation phase (plant height, 100-120 cm). By subsequent mowing in the tasseling phase, the amount of total proteins and mineral substances in the biomass decreased, while the amount of carbohydrates and cellulose significantly increased. The content of lipids in the samples tested differed depending on the cultivar, but this variation was not statistically significant. By increasing the intensity of plant nitrogen nutrition, the total protein content in the tested samples was increased. Due to the large amounts of nonprotein nitrogen compounds, the fraction of digestible proteins did not increase. According to the established chemical composition of the silage sorghum hay, the total digestibility of nutritive components of the tested samples was determined to be satisfactory, above 51%. The highest quality biomass was obtained by mowing the hybrid of sorghum and Sudan grass during the stem elongation phase. The most suitable nitrogen dose of 80-120 kg and harvest during the tasseling period were the best for all 3 cultivars.

Key words: Chemical composition, fodder sorghum, harvest period, nitrogen, Sudan grass

Introduction

Sorghum is a highly drought-tolerant field crop. It has low water requirements, and therefore it is widely used as a fodder crop in many regions of the world. However, as with other crops, high yield can be achieved only through the use of suitable agronomic practices (ICRISAT/FAO 1996; Zerbini and Thomas 2003). In order to expand the use of sorghum as a forage crop, its tendency to lodging, a characteristic of the tall forage sorghum types, must be overcome

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(Miron et al. 2005). Another obstacle to the expanded use of tall forage sorghum is its insufficient accumulation of dry matter content (Miron et al. 2006).

Today there are different cultivars of sorghum that are grown for various purposes, either for animal feed production or for human nutrition, especially cultivars whose seeds have a high nutritional value and contain few harmful substances. These plant species have special importance in the agricultural production of developing countries (Taylor 2004). Sorghum has an important role in the production of ethanol and other bioindustrial products such as bioplastics (McLaren et al. 2003). Previous tests performed on these plant species have shown that their seeds contain significant quantities of various polyphenol compounds (Dykes and Rooney 2006). The biomass of fodder sorghum, Sudan grass, and their hybrid is usually used fresh or for preparation of silage, while it is rarely used for the preparation of hay or grazing (Erić et al. 1999). Depending on use of the biomass (hay, silage, or fresh), suitable agronomic practices are applied. If these plants are grown for fresh biomass or for grazing, sowing is denser, with higher consumption of seed per hectare, while for silage production, plants are grown on a larger vegetation area (Kruzin and Časovskih 1997). Plant nutrition is of great importance for obtaining a higher yield and higher nutritive values of the biomass. Previous studies dealing with this problem confirm the positive influence of supplementary nutrition on the quality of fodder sorghum. Under conditions of increased nitrogen nutrition, the yield of biomass, the dry matter, and the total protein content are increased (Mitrović 1988). The yield represents the plant's potential to accumulate dry matter, as well as its adaptability to different agroecological conditions. The main criteria for the evaluation of the nutritional value are the increase of digestible matter and the decrease of lignin content (Casler 2001). In the agroecological conditions of eastern Serbia, in less fertile soils, 150 kg ha^{-1} of nitrogen is needed. Adequate plant nutrition not only increases fodder yield and quality, but can also affect the amount of the harmful durin alkaloid (Hugues 1967). In the digestive tract of domestic animals, the alkaloid durin dissolves into HCN (Erić and Đjukić 2004).

The highest concentration of alkaloids is in the leaves of young plants when they reach a height of 50-60 cm (Piedallu 1923).

The purpose of this research was to determine the level of tested chemical parameters, as well as overall biomass digestibility of Sudan grass, fodder sorghum, and their hybrid in various phases of the harvest maturity, and the influence of added quantities of nitrogen during top-dressing.

Materials and methods

This study was performed during 2007 and 2008 at the Radmilovac experimental field, located 30 km northeast of Belgrade, for the purpose of estimation of effects of nitrogen quantity and harvesting time on the chemical composition of biomass of Sudan grass, fodder sorghum, and their hybrid. For the preparation of representative samples, previously naturally dried vegetative biomass (stems and leaves) was used of Sudan grass Zora (bred at the Institute of Crop and Vegetable Science, Novi Sad, 1983), fodder sorghum NS-Dzin (bred at the Institute of Crop and Vegetable Science, Novi Sad, 1983), and sorghum and Sudan grass hybrid Siloking (bred at the Institute of Crop and Vegetable Science, Novi Sad, 2007) (Cultivar index of agricultural plants 2008). Tables 1 and 2 give climatic data of the research area for these 2 years, with average temperature and precipitation, and chemical soil characteristics, respectively.

The type of soil in which the plants were bred, under the conditions of a natural water regime, was cambisol (pH 5.2), and the organic matter content was 3.6%. For plant nutrition, the following quantities of nitrogen, in the form of ammonium nitrate fertilizer, were used: 105 kg ha^{-1} (N_2), 150 kg ha^{-1} (N_3), 180 kg ha^{-1} (N_4), and control (N_1) natural nitrogen reserve, 60 kg ha^{-1}. The nitrogen was introduced to the soil before the plants were sown, as follows. During plowing (September), 150 kg ha^{-1} of urea with 42% nitrogen was introduced to all experimental plots, except the control; the rest of the nitrogen was introduced to the soil in seedbeds. Phosphorus and potassium fertilizers were not used. Irrigation was not applied during the experiments. For the purpose of comparing the nitrogen influence, fodder sorghum was sown with the natural nitrogen reserve (N_1). The

Table 1. Monthly climatic data for 2007 and 2008 for the Radmilovac research area, average temperature, and precipitation data from the Republic Hydrometeorological Service of Serbia.

Year	Parameter	Month						Average
		Apr	May	Jun	Jul	Aug	Sep	
2007	Temperature (°C)	14.7	19.8	24.4	26.9	25.2	15.8	21.13
	Precipitation (mm)	4	79	108	18	72	35	316
2008	Temperature(°C)	14.2	19.3	23.0	23.6	24.2	17.5	20.3
	Precipitation(mm)	35	61	45	64	46	68	264
10-year average	Temperature(°C)	15.0	26.2	22.8	24.8	24.6	17.6	20.76
	Precipitation (mm)	15	58	102	53.6	54.3	49.3	129.3

Table 2. Chemical soil characteristics data of the Radmilovac research area, before fertilization, from Laboratory Agrolab, Institute "Tamiš," Pančevo, Serbia.

Depth (cm)	pH		$CaCO_3$ (%)	Humus (%)	Nitrogen (%)	mg 100 g^{-1} of soil	
	H_2O	n/1KCl				P_2O_5	K_2O
0-30	6.10	5.20	1.3	3.5	0.17	2.5	27.2

experiment utilized a randomized block, split-split plot design with 3 replications. The planting dates were 10 April 2007 and 13 April 2008. Plants were seeded in plots that measured 10 × 2.5 m, in 10 rows, with a distance between rows of 0.25 m. Plants were harvested by hand the same year, on 1 August 2007 and 4 August 2008 during the stem elongation phase, and on 29 August 2007 and 31 August 2008 during the tasseling period.

In the present study, the overall protein content was determined using the macro-Kjeldahl method (AACC 1969). Overall lipid content was determined by petrol-ether extraction of lipids (Soxhlet method). Cellulose content was determined using the Weende method, and overall ash content was determined by organic matter combustion at 550 °C, measuring the residue (Rakić 2006; Rakić et al. 2006). Carbohydrate content was determined by subtracting quantities of overall proteins, cellulose, and overall lipids from the quantity of organic matter. Digestibility of silage sorghum hay was obtained using the digestibility index, calculated per 100 grams of dry matter. (Đorđević et al. 2003). Analysis of experimental data was conducted using analytical statistical methods from the Statistica 7.1 for Windows (Stat Soft 2005) software package. Examination of differences between the treatments and evaluation of their importance was conducted using the analysis of variance method (MANOVA), followed by the LSD test with significance thresholds of 1% and 5%. With the intent of making objective conclusions about the influence of tested factors on the chemical composition of analyzed samples and the possibility of implementation of parametric tests (analysis of variance and LSD test), the homogeneity of variance was tested with Hartley's, Cochran's, Bartlett's, and Levene's tests. In all cases, the requirement of homogeneity and the possibility of applying parametric tests were fulfilled.

Results

All of the obtained results represent the mid-values acquired during a 2-year research period. The results of quantitative chemical analysis of tested samples of 3 types of commercial fodder sorghum cultivars, Sudan grass Zora, fodder sorghum NS-Dzin, and their hybrid Siloking, are presented in Table 3.

Individual variation of energy and constitutive components were dependent on mowing time and the amount on nitrogen used in plant nutrition. Total ash content variations were significant depending on cultivars and mowing time. Ash content was

Table 3. Chemical compositions of dry biomass samples of Sudan grass, fodder sorghum, and their hybrid.

Cultivars	Harvest period	Nitrogen amounts N_1	N_2	N_3	N_4	$\bar{x} \pm S\bar{x}$
		Ash content %				
Zora	Stem elongation	10.80	10.36	10.92	10.32	10.08 ± 0.21
	Tasseling	9.71	9.66	9.54	9.36	
Siloking	Stem elongation	11.56	11.33	11.42	11.50	10.68 ± 0.19
	Tasseling	10.48	10.04	9.96	10.12	
NS-Dzin	Stem elongation	10.58	11.06	11.32	10.99	10.72 ± 0.07
	Tasseling	10.36	10.48	10.42	10.54	
	$\bar{x} \pm S\bar{x}$	10.58 ± 0.18	10.32 ± 0.17	10.60 ± 0.22	10.47 ± 0.19	
		Crude protein content %				
Zora	Stem elongation	11.48	12.82	12.56	12.92	11.33 ± 0.29
	Tasseling	9.51	10.33	10.18	10.38	
Siloking	Stem elongation	11.96	12.88	12.98	13.32	11.59 ± 0.29
	Tasseling	9.73	10.17	10.60	11.11	
NS-Dzin	Stem elongation	11.13	12.08	12.84	13.48	11.64 ± 0.22
	Tasseling	10.04	10.94	11.29	11.26	
	$\bar{x} \pm S\bar{x}$	10.64 ± 0.24	11.59 ± 0.29	11.74 ± 0.30	12.11^{a} ± 0.30	
		Cellulose content %				
Zora	Stem elongation	29.13	28.96	29.15	28.35	29.34 ± 0.15
	Tasseling	29.98	29.20	29.48	29.81	
Siloking	Stem elongation	30.74	31.63	31.14	30.22	31.49 ± 0.24
	Tasseling	30.52	31.96	32.34	33.36	
NS-Dzin	Stem elongation	30.88	30.26	30.59	29.97	31.19 ± 0.21
	Tasseling	32.08	32.45	32.67	30.65	
	$\bar{x} \pm S\bar{x}$	30.56 ± 0.25	30.80 ± 0.38	30.90 ± 0.32	30.45 ± 0.38	
		Lipid content %				
Zora	Stem elongation	1.73	1.67	1.68	1.69	1.69 ± 0.07
	Tasseling	1.61	1.64	1.72	1.78	
Siloking	Stem elongation	2.18	2.28	2.16	2.25	2.13 ± 0.04
	Tasseling	2.19	2.01	2.06	1.94	
NS-Dzin	Stem elongation	2.17	2.23	2.24	2.13	2.20 ± 0.02
	Tasseling	2.32	2.17	2.14	2.22	
	$\bar{x} \pm S\bar{x}$	2.03 ± 0.07	2.00 ± 0.10	2.00 ± 0.08	2.00 ± 0.06	
		Nitrogen-free extract (NFE) %				
Zora	Stem elongation	46.86	46.19	45.69	46.72	47.71 ± 0.36
	Tasseling	49.19	49.17	49.08	48.67	
Siloking	Stem elongation	43.56	41.88	42.30	42.71	43.98 ± 0.37
	Tasseling	47.08	45.82	45.04	43.47	
NS-Dzin	Stem elongation	45.24	44.37	43.01	43.43	44.25 ± 0.19
	Tasseling	45.20	43.96	43.48	45.33	
	$\bar{x} \pm S\bar{x}$	46.19 ± 0.47	45.25 ± 0.58	44.77 ± 0.57	45.05 ± 0.52	

lowest in the dry biomass samples of cultivar Zora (10.08%), and highest in the NS-Dzin cultivar samples (10.72%). Total ash content was increased, at an overall average of 6%, by subsequent mowing. The quantity of nitrogen used in top-dressing did not affect the total quantity of ash in the tested samples.

The quantities of nitrogen used as supplementary nutrition and the mowing time influenced the overall content of proteins in the biomass, individually as well as through the interaction between the cultivar and its mowing time. In tested mowing terms, with increased nitrogen use, the total protein content in the biomass also increased. The lowest total protein content in the biomass was found in the N_1 samples, 10.64%. Enhanced plant nitrogen nutrition influenced the overall protein content, which was the highest in samples N_4, 12.11%. The mowing time also influenced the protein value of the tested biomass samples. The dried biomass samples for all 3 cultivars had lower total protein content when the plants were mowed during the tasseling phase, while there were no significant differences in total protein content among the cultivars. Group treatments (mowing time and cultivar), as well as all of their interactions, influenced the cellulose content in the dried biomass samples. Analysis of individual treatments showed that Sudan grass biomass in all varieties of nitrogen nutrition and all mowing phases had significantly lower cellulose content than fodder sorghum or the hybrid. Cellulose content in the tested samples also showed significant variations due to mowing time. When mowed during the tasseling phase, Siloking cultivar samples had lower cellulose content than when mowed during the stem elongation phase. For the 2 other tested cultivars, the cellulose content was higher in the biomass obtained by subsequent mowing.

The cultivars included in this research affected the lipid content in tested samples of the dried biomass. The lowest lipid content was found in samples of dried plant material of cultivar Zora, 1.69%. The total lipid content was 2.13% in samples of the Siloking hybrid and 2.20% in the NS-Dzin cultivar samples. Neither mowing time nor the quantity of nitrogen used for nutrition affected the synthesis and accumulation of lipids in dried biomass samples.

The tested chemical parameters demonstrated significant variations in the content of nitrogen-free extract (NFE) within the analyzed samples. Individual treatment, as well as the interactions between the cultivar and its mowing time and the interactions between the cultivar, its mowing time, and the nitrogen amount, influenced the content of NFE. Nitrogen nutrition had a decreasing influence on carbohydrate content in the dried biomass, so that the highest values for all 3 cultivars were in the N_1 variety, 46.19%. Increasing the nitrogen quantity in plant nutrition decreased the NFE in the dried biomass. Mowing time indicated that as the plants aged (the tasseling phase), the NFE also increased. The NFE differed mainly among cultivars. Hybrid Siloking had the lowest NFE, 42.98%; cultivar NS-Dzin, 44.25%; and Zora, the highest, 47.71%.

The statistical significance of the chemical component variability for tested parameters and their interactions is presented in Table 4.

The organic substance digestibility indexes of Sudan grass hay were based on the determined chemical content of the analyzed samples as indicated by the nutritive value tables (Đorđević et al. 2003). The digestibility of the nutritive substances in each component was then calculated, and the changes and interactions among them were tested. The results are shown in Tables 5 and 6.

All tested factors and interactions between the cultivar and its harvest period demonstrated a significant influence on digestible protein content. The lowest level of digestible proteins was observed in sorghum biomass obtained during the tasseling phase (Zora, 4.75%; Siloking, 4.86%; and NS-Dzin, 5.02%). A nitrogen quantity of 105 kg ha^{-1} used for plant nutrition caused an increase of digestible protein content, but when larger quantities were used, no such effect was recorded. Harvest time had the highest impact on the digestible protein content in the tested samples. Biomass obtained by earlier mowing had the highest protein amount that domestic animals could effectively use. By subsequent mowing, the content was reduced, because larger quantities of proteins moved from the vegetative to generative organs. Stem elongation can be defined as the technological maturity of sorghums used for hay production.

Table 4. Statistical summary of changes in chemical characteristics according to cultivar, harvest period, and nitrogen amount.

Chemical characteristics	Factors	Degrees of freedom (df)	MS	Test		
				F	LSD	
					0.05	0.01
Ash content %	Cultivars (A)	2	3.038	7.796*	0.353	0.465
	Harvest period (B)	1	13.703	35.164**	0.288	0.380
	Nitrogen amounts (C)	3	0.284	0.728^{NS}	0.408	0.537
	(A × B)	2	0.521	1.336^{NS}	0.500	0.658
	(A × C)	6	0.442	1.134^{NS}	0.707	0.930
	(B × C)	3	0.414	1.061^{NS}	0.577	0.760
	(A × B × C)	6	0.127	0.326^{NS}	0.999	1.316
	Error	48	0.390			
Crude protein content %	Cultivars (A)	2	0.665	1.989^{NS}	0.327	0.430
	Harvest period (B)	1	74.501	222.722**	0.267	0.351
	Nitrogen amounts (C)	3	7.020	20.986**	0.378	0.497
	(A × B)	2	1.364	4.080*	0.462	0.609
	(A × C)	6	0.371	1.108^{NS}	0.654	0.861
	(B × C)	3	0.201	0.602^{NS}	0.534	0.703
	(A × B × C)	6	0.163	0.488^{NS}	0.925	1.217
	Error	48	0.334			
Cellulose content %	Cultivars (A)	2	32.535	87.117**	0.346	0.455
	Harvest period (B)	1	22.714	60.818**	0.282	0.372
	Nitrogen amounts (C)	3	0.776	2.077^{NS}	0.400	0.526
	(A × B)	2	1.003	2.686^{NS}	0.489	0.644
	(A × C)	6	1.741	4.661**	0.692	0.911
	(B × C)	3	0.832	2.228^{NS}	0.565	0.744
	(A × B × C)	6	1.692	4.530**	0.979	1.288
	Error	48	0.374			
Lipid content %	Cultivars (A)	2	1.851	22.683**	0.162	0.213
	Harvest period (B)	1	0.045	1.551^{NS}	0.132	0.174
	Nitrogen amounts (C)	3	0.005	0.062^{NS}	0.187	0.246
	(A × B)	2	0.063	0.775^{NS}	0.229	0.302
	(A × C)	6	0.088	0.108^{NS}	0.324	0.426
	(B × C)	3	0.013	0.156^{NS}	0.264	0.348
	(A × B × C)	6	0.027	0.329^{NS}	0.458	0.603
	Error	48	0.082			

^{NS}Nonsignificant, *5% significance, **1% significance

Table 5. Content of digestible matter in dry biomass samples of Sudan grass, fodder sorghum, and their hybrid, per 100 grams of dry substance.

Cultivars	Harvest period	Nitrogen amounts				$\bar{x} \pm S\bar{x}$
		N_1	N_2	N_3	N_4	
		Digestible protein content % (Coef. 50)				
Zora	Stem elongation	5.74	6.41	6.28	6.46	5.64 ± 0.14
	Tasseling	4.75	5.16	5.09	5.19	
Siloking	Stem elongation	5.98	6.44	6.49	6.66	5.80 ± 0.14
	Tasseling	4.86	5.08	5.30	5.55	
NS-Dzin	Stem elongation	5.56	6.04	6.42	6.74	5.82 ± 0.11
	Tasseling	5.02	5.47	5.64	5.63	
	$\bar{x} \pm S\bar{x}$	5.32 ± 0.12	5.77 ± 0.15	5.87 ± 0.15	6.04 ± 0.15	
		Digestible cellulose content % (Coef. 64)				
Zora	Stem elongation	18.64	18.53	18.65	18.14	18.72 ± 0.09
	Tasseling	19.18	18.68	18.86	19.07	
Siloking	Stem elongation	19.67	20.24	19.92	19.34	20.15 ± 0.15
	Tasseling	19.53	20.45	20.69	21.35	
NS-Dzin	Stem elongation	19.76	19.36	19.57	19.18	19.96 ± 0.13
	Tasseling	20.53	20.76	20.91	19.62	
	$\bar{x} \pm S\bar{x}$	19.56 ± 0.16	19.68 ± 0.23	19.77 ± 0.21	19.45 ± 0.25	
		Digestible lipid content % (Coef. 52)				
Zora	Stem elongation	0.899	0.868	0.873	0.878	0.88 ± 0.04
	Tasseling	0.837	0.852	0.894	0.925	
Siloking	Stem elongation	1.133	1.185	1.123	1.171	1.11 ± 0.02
	Tasseling	1.138	1.045	1.071	1.001	
NS-Dzin	Stem elongation	1.128	1.590	1.164	1.107	1.14 ± 0.01
	Tasseling	1.144	1.128	1.112	1.154	
	$\bar{x} \pm S\bar{x}$	1.06 ± 0.04	1.04 ± 0.05	1.04 ± 0.04	1.04 ± 0.03	
		Digestible nitrogen-free extract (NFE) % (Coef. 56)				
Zora	Stem elongation	26.24	25.86	25.58	26.16	26.71 ± 0.20
	Tasseling	27.54	27.52	27.48	27.25	
Siloking	Stem elongation	24.39	23.45	23.68	23.91	24.63 ± 0.21
	Tasseling	26.36	25.65	25.22	24.34	
NS-Dzin	Stem elongation	25.33	24.84	24.08	24.32	24.78 ± 0.11
	Tasseling	25.31	24.61	24.34	25.38	
	$\bar{x} \pm S\bar{x}$	25.86 ± 0.26	25.33 ± 0.33	25.07 ± 0.32	25.23 ± 0.29	

Table 6. Statistical summary of changes in nutritive substances according to cultivar, harvest period, and nitrogen amount, per 100 grams of dry substance.

Nutritive substances	Factors	Degrees of freedom (df)	MS	Test		
				F	LSD	
					0.05	0.01
Digestible protein content	Cultivars (A)	2	0.235	3.183^{NS}	0.154	0.202
	Harvest period (B)	1	19.396	263.123**	0.125	0.165
	Nitrogen amounts (C)	3	1.697	23.026**	0.177	0.233
	(A × B)	2	0.373	5.058*	0.217	0.286
	(A × C)	6	0.072	0.979^{NS}	0.307	0.404
	(B × C)	3	0.061	0.822^{NS}	0.251	0.330
	(A × B × C)	6	0.044	0.593^{NS}	0.434	0.572
	Error	48	0.074			
Digestible cellulose content	Cultivars (A)	2	14.442	108.534**	0.206	0.272
	Harvest period (B)	1	9.304	69.919**	0.168	0.222
	Nitrogen amounts (C)	3	0.353	2.652^{NS}	0.238	0.314
	(A × B)	2	0.411	3.087^{NS}	0.292	0.384
	(A × C)	6	0.732	5.505**	0.413	0.543
	(B × C)	3	0.440	3.309*	0.337	0.444
	(A × B × C)	6	0.704	5.289**	0.584	0.768
	Error	48	0.133			
Digestible lipid content	Cultivars (A)	2	0.501	22.683**	0.084	0.111
	Harvest period (B)	1	0.012	0.551^{NS}	0.069	0.090
	Nitrogen amounts (C)	3	0.001	0.062^{NS}	0.097	0.128
	(A × B)	2	0.017	0.775^{NS}	0.119	0.156
	(A × C)	6	0.002	0.108^{NS}	0.168	0.221
	(B × C)	3	0.003	0.150^{NS}	0.137	0.181
	(A × B × C)	6	0.007	0.329^{NS}	0.238	0.313
	Error	48	0.022			
Nitrogen-free extract (NFE)	Cultivars (A)	2	32.281	142.294**	0.269	0.355
	Harvest period (B)	1	21.722	95.750**	0.220	0.290
	Nitrogen amounts (C)	3	2.142	9.444**	0.311	0.410
	(A × B)	2	3.101	13.669**	0.381	0.502
	(A × C)	6	0.462	2.037^{NS}	0.539	0.709
	(B × C)	3	0.131	0.578^{NS}	0.440	0.579
	(A × B × C)	6	0.738	3.256**	0.762	1.003
	Error	48	0.227			

^{NS}Nonsignificant, *5% significance, **1% significance

Harvest time and cultivar significantly influenced the variation of digestible cellulose content, while the nitrogen amount and the interaction between the cultivar and the harvest period had no such effect.

Digestible lipids were the least represented components in all tested samples; their values ranged from 0.837% to 1.590%. Analysis of digestible lipid content showed significant variations only among cultivars, while the other parameters tested had no influence on this value.

The most common component of sorghum hay is digestible NFE. In relation to the tested parameters, statistically significant variations of NFE were manifested within all 3 treatments, and in the interaction between the cultivar and the nitrogen amount and the interaction between the harvest period and the nitrogen amount. Subsequent mowing produced more digestible NFE in the hay of all 3 cultivars. The total nutrient digestibility results for the hay of Sudan grass Zora, fodder sorghum NS-Dzin, and their hybrid Siloking were above 50%, which can be rated as a satisfactory nutritional value.

The average yield of naturally dried vegetative biomass, hay (Table 7), during stem elongation was 7.4 t ha^{-1} and, during tasseling, 8.3 t ha^{-1}. The nitrogen had a significant influence on yield increase in quantities up to 150 kg ha^{-1}. Statistically significant differences appeared among the cultivars. The highest yield of naturally dried vegetative biomass (hay) during stem elongation was with Siloking at 8.26 t ha^{-1}, and, during tasseling, with Zora at 9.73 t ha^{-1}. Fodder sorghum NS-Dzin had the lowest yield of hay. The average yield of hay was considerably higher in 2008 than in 2007. In Table 8, the statistical summary of dry weight yield according to cultivar, nitrogen amount, and year is presented.

Discussion

The experimental soil, with a natural nitrogen reserve (N_1), was rich in easily acceptable nitrogen and had a high content of humus. However, the high acidity of the soil solution (pH in n/1KCl, 5.2) unfavorably influenced nitrogen mineralization from organic complexes. Increased plant nutrition with

Table 7. Yield of naturally dried vegetative biomass (hay), t ha^{-1}.

Cultivars	Year	Nitrogen amount				$\bar{x} \pm S\bar{x}$
		N_1	N_2	N_3	N_4	
		Stem elongation				
Zora	2007	4.88	6.16	7.77	8.09	7.21 ± 0.245
	2008	6.49	7.54	8.36	8.40	
Siloking	2007	5.88	8.21	9.69	9.18	8.26 ± 0.263
	2008	6.66	8.32	8.70	9.46	
NS-Dzin	2007	4.54	6.21	6.77	6.98	6.78 ± 0.241
	2008	6.05	7.09	8.21	8.38	
$\bar{x} \pm S\bar{x}$		5.72 ± 0.186	7.26 ± 0.209	8.23 ± 0.216	8.41 ± 0.194	
		Tasseling				
Zora	2007	7.76	9.71	10.04	10.27	9.73 ± 0.218
	2008	8.28	10.76	10.52	10.48	
Siloking	2007	4.87	7.95	9.25	9.39	8.67 ± 0.324
	2008	8.76	9.41	10.08	9.64	
NS-Dzin	2007	4.51	5.58	6.01	6.41	6.52 ± 0.230
	2008	6.62	7.12	7.71	8.18	
$\bar{x} \pm S\bar{x}$		6.80 ± 0.397	8.42 ± 0.422	8.93 ± 0.387	9.06 ± 0.339	

Table 8. Statistical summary of dry weight yield according to cultivar, nitrogen amount, and year.

Phase	Factors	Degrees of freedom (df)	MS	Test		
				F	LSD	
					0.05	0.01
Stem elongation	Cultivars (A)	2	14.0043	6937.005**	0.0261	0.0348
	Nitrogen amounts (B)	3	6.5827	3260.727**	0.0301	0.0402
	Years (C)	1	12.5751	6229.065**	0.0213	0.0284
	(A × B)	6	1.1046	547.179**	0.0506	0.0666
	(A × C)	2	0.2385	118.124**	0.0358	0.0471
	(B × C)	3	20.5355	10172.258**	0.0413	0.0544
	(A × B × C)	6	0.3595	178.092**	0.0716	0.0942
	Error	46	0.0020			
Tasseling	Cultivars (A)	2	64.2402	4938.684**	0.0663	0.0885
	Nitrogen amounts (B)	3	13.8938	1068.134**	0.0765	0.1022
	Years (C)	1	13.7463	1056.134**	0.0541	0.0722
	(A × B)	6	1.5834	121.733**	0.1290	0.1698
	(A × C)	2	0.4496	34.565**	0.0912	0.1201
	(B × C)	3	13.1794	1013.213**	0.1053	0.1387
	(A × B × C)	6	1.2831	98.642**	0.1825	0.2402
	Error	46	0.0130			

**1% significance

nitrogen (N_2, N_3, N_4) in the form of ammonium nitrate fertilizer had positive effects on overall protein content in the tested biomass samples.

The research was based on naturally dried biomass of 3 cultivars of fodder sorghums that are widely used in the southeastern Balkans. The samples were actually dried parts of stems and leaves that were selected randomly. The homogeneity of the chemical composition and the total digestible substance content of the tested samples during the 2-year research period enabled us to present the obtained results as average values. However, we tended to make comparisons among the 3 cultivars during 2 phases of plant growth, because better results were obtained when mowing was performed during the harvest maturity of the plants, when their height was 100-120 cm (Miron et al. 2007). In this study, during the summer cycle (Tables 3 and 5), the chemical compositions of the analyzed samples and their overall digestibility were in accordance with the results achieved in previous studies, which were concerned with silage composition, carried out in different locations (Carmi et al. 2006; Yosef et al. 2009).

In addition to the energetic and constitutive substances of fodder sorghum (Tables 3 and 5), which are the main subjects of this study, previous research on other cultivars of this sorghum species determined the presence of protective components, such as broad-spectrum polyphenol compounds (Dykes and Rooney 2006). In comparison to fodder corn, some cultivars of fodder sorghum have higher nutritive values (Oliver et al. 2004). Previous research dealing with comparative analysis of the biomass quality of fodder sorghum and corn (Miron et al. 2007) and their influence on dairy cow lactation pointed out that the nutritive characteristics of sorghum biomass are better, and because of that, milk with a higher content of milk-fat is obtained. The dry substance content in the biomass samples obtained by mowing the plants during the stem elongation phase was higher than in samples obtained during the tasseling phase. This parameter is of interest for animal feed manufacturers. Nitrogen used in plant nutrition did not influence the mineral substance content (ash) in the total dry substance content of the tested samples. However, comparing samples of tested species, cultivars, and mowing time, their variations are fairly significant and amount to 6% on average. According to literature data (Downes et al. 1974; Miron et al. 2007; Fahmy et al. 2010), the total mineral substance content in the dried biomass of fodder sorghum is in accordance with the results obtained by the present research.

The crude protein content in the tested samples depended on mowing time. Hay with a higher content of total and digestible proteins was obtained by earlier mowing (intense stem elongation phase). In subsequent mowing, the obtained biomass had lower protein values. In previous research (Wedig et al. 1987; Marsalis et al. 2010) on the chemical composition of silage sorghum and its hybrids, it was determined that total protein content varied from 8.7% to 10.9%, which is in accordance with the results of this study. In comparison to other analyzed components, total lipid content was proportionally the smallest, and therefore its digestibility had no influence on the total digestibility percentage of this nutritive. In tested samples, cellulose substances were significantly more represented in comparison to other nutritive substances. It was determined by previous research (Wedig et al. 1987; Fahmy et al. 2010) on crude cellulose content that its content ranges between 30% and 40%. Digestibility of crude cellulose had a significant influence on total hay digestibility of all cultivar samples in this research. The samples of dry biomass obtained by mowing during the intensive stem elongation phase had the highest nutritive value. It can be concluded that the best harvest time is the period before the tassels appear, that is, when the plant reaches its maximum height. The optimal mowing time depends on the cultivar and weather conditions during the vegetation period. These results are compatible with results and references from a previous study (Çamakçı et al. 1999). In the agroecological conditions of the Serbian highlands, plants reach the height of 100-150 cm in the first swath, before the tasseling phase. If the water levels are adequate, there is a possibility for one more swath, but in that case, plants enter the tasseling phase when the maximum stem height is up to 100 cm. Results of these studies showed that voluminous, high quality fodder could be obtained by earlier as well as by subsequent mowing of these cultivars, because all samples in this study had over 51% of total digestible substances with a significant ratio of digestible proteins (Table 5).

Nitrogen used in plant nutrition had no influence on increasing the total digestible substance content in dried biomass samples. Sorghums are plants with a strong root system and good suction power, and they are well capable of using unused nitrogen salts necessary for the nutrition of preceding crops. The rainfall amount and its layout have a significant impact on the effectiveness of nitrogen use. Erić and Ćupina (2001) showed that only favorable water levels (crop irrigation after each swath) justified an increase of nitrogen quantity in plant nutrition.

The results for the average yield of naturally dried vegetative biomass, hay (Table 7), are in accordance with previous studies (Erić and Ćupina 2001; Miron 2005, 2006). In the production of voluminous fodder, silage corn can be successfully replaced with Sudan grass and fodder sorghum (Erić and Ćupina 2001). As the western Balkans take on more and more semiarid climate characteristics with very dry and hot summers, silage corn breeding becomes insecure due to the high plant sensibility to drought in harvest periods with the largest water consumption. Sorghums are more tolerant to drought than corn, and lately they are becoming more interesting as fodder crop, especially Sudan grass, which has good regenerative qualities in adequate weather conditions and can give 2 or 3 swaths per year. The main asset of sorghum is that its biomass is easy to dry and that it is suitable for silage. The quality of the sorghum biomass is similar to the corn biomass quality.

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