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THE GENOTYPE TRAITS OF FORAGE SORGHUM, SUDAN GRASS AND THEIR INTERSPECIES HYBRID IN THE CONDITIONS OF INTENSIVE NITROGEN NUTRITION

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The subject of this study is a three-year study (carried out during 2007, 2008 and 2009) of the morphological characteristics variability in three genotypes *NS-Džin* (Forage Sorghum), *Zora* (Sudan grass) and *Siloking* (interspecies hybrid) depending on the amount of nitrogen used for plant nutrition. For the height and mass analysis of fresh stems and leaves as well as leaf mass and leaf portion in the total biomass, samples were taken from the first swath when the effect of the used nitrogen amounts was the greatest. The results have shown that there are significant variations in the

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tested properties between the genotypes. The *Siloking* genotype had the highest total biomass during all three years. The largest leaf mass was found in the *NS-Džin* genotype, while the Zora genotype had the highest leaf portion in the three-year average. The effect of nitrogen use depended on the weather conditions, as well as the layout of the rainfall, so that the optimal quantity was 105 kg ha^{-1} during the first and the second year, and 150 kg ha $^{-1}$ during the third year.

*Key words: g*enotype, interspecies hybrid, nitrogen nutrition, sorghum, sudan grass

INTRODUCTION

The cultivated species of the *Sorghum* genus are highly tolerant to drought in all growing period, which is why they have become very important for semi-arid areas with continental climate. However, large biomass production of and high the number of per year can be achieved in conditions of optimum moisture and nitrogen plant nutrition (ZERBINI and THOMAS, 2003, IKANOVIC et *al*, 2010). Besides Forage Sorghum and Sudan grass, interspecies hybrids of these two plants are now grown worldwide. These genotypes are characterized by high biomass quality and low harmful substance content. They also regenerate well and can offer more swath possibilities (BERENJI, 1988, OSTOJIĆ *et al*., 1992, GLAMOCLIJA *et al.*, 2010). Therefore, interspecies hybrids are very interesting for breeding, and biomass represents excellent voluminous feed for dairy animals. In addition to water amount, the biomass productivity and quality is also highly influenced by plant nutrition. Previous studies which have dealt with this problem have confirmed the positive impact of supplementary nutrition on the quality of Forage Sorghum. The role of nitrogen in plant metabolism is already sufficiently explored and well known. Optimal supply of this element in plants provides an intense activity in the formation of nitrogen compounds which are used for the synthesis of spare proteins (ERIĆ and ĆUPINA, 2001). Using large quantities of nitrogen makes the production much more expensive which is why the question of rational use of mineral fertilizers needs to be raised (BOOKER *et al.* 2007). This problem is relevant for environment protection as well because unused nitrogen amounts represent a potential pollution source for of the entire ecosystem. Most authors suggest that these problems can be solved by selecting optimal genotypes that would more effectively use nitrogen for supplemental plants nutrition (MITROVIĆ, 1988, CASLER, 2001., MCLAREN *et al.*, 2003). It also would be important to identify the genotypes that hold any desirable traits related to nitrogen nutrition include them in further breeding programs.

MATERIAL AND METHODS

The tests were performed during the 2007-2009 period. A two-factorial experiment was set up in the Radmilovac experimental field using a randomized block system with 10 repetitions. The size of the experimental plots was 10 m^2 (5 m x 2 m). Three genotypes were studied: *Džin* (Forage Sorghum bred in 1983), *Zora*

(Sudan grass bred in 1983) and *Siloking* (interspecies hybrid bred in 2007) which were all selected by the by the Institute of Field and Vegetable Crops in Novi Sad, depending on the amount of nitrogen used in pre-seeding preparation. These are the 105 kg ha^{-1} (N_2), 150 kg ha^{-1} (N_3), 180 kg ha^{-1} (N_4) and the control natural soil fertility (N_1) - 60 kg ha^{-1}. Standard cropping methods for growing Forage Sorghum were used. Swath was performed at the beginning of the tasseling stage during the second half of July. For the analysis of morphological traits (plant height, stem weight, leaf mass present on the stem and the portion of leaves in the total biomass) samples were taken from freshly mown biomass. During the observed period, the weather conditions provided less than average rainfall in the first and second year and more rainfall in the third year. Thermal conditions were on the average level for the area of the Radmilovac experimental field (Tab.1).

Table 1 Monthly rainfall amount (mm) and average monthly temperature for Belgrade, ^0C (Republic Hydrometeorological Service of Serbia)

Year	Parameter	Month						Average
		IV	V	VI	VII	VIII	IX	
2007	Temperature	15	20	24	27	25	16	21^{0}C
	Rainfall	4	79	108	18	72	35	316 mm
2008	Temperature	14	19	23	24	24	18	20^{0}C
	Rainfall	35	61	45	64	46	68	319 mm
2009	Temperature	16	20	21	24	25	20	21^{0}C
	Rainfall	6	34	153	79	45	45	362 mm
20- year	Temperature	15	26	23	25	25	18	22^{0}C
Average	Rainfall	35	58	102	54	54	49	352 mm

The analysis of experimental data was conducted using analytical statistics from the statistical package STATISTICA 8 for Windows (StatSoft). In order to make objective conclusions about the impact of the observed factors on the examined Forage Sorghum traits, and in order to enable the application of parametric tests (analysis of variance and LSD-test), the homogeneity of variances was tested using the Hartley, Cochran, Bartlett and Levene tests.

The results of these tests indicate that the variances of the investigated characteristics are homogeneous. Each of the obtained indicators was processed through statistical analysis using descriptive statistics (for indicators on an annual basis). The significance of the differences between Forage Sorghum varieties, the examined N doses, and their interaction was conducted using variance analysis for the two-factorial experiment (MANOVA) and individual differences in average LSD-test values were conducted using risk levels of 5% and 1% (SIMIC, *et al.*, 2009 and SIMIC,M. *et al,* 2009).

The relative dependence of properties was measured using Pearson's correlation coefficient, and was tested at the 5% and 1% levels of significance.

Based on the I-distance the ranking of observed nitrogen amounts per year was carried out:

RESULTS AND DISCUSSION

The investigated morphological traits showed a large dependence on genotype and the intensity of nitrogen plant nutrition (Tab. 2 and 3).

Table 2 The influence of genotype and nitrogen on the observed characteristics, 2007/9

Years	Plant Height (m)	Leaves Mass (g)	Stem Mass (g)	Leaves Portion, %
Genotype (A)		*2007*		
Siloking	1.663[b]	30.252[b]	90.757[a]	25.3[c]
NS Džin	1.646[b]	42.047[a]	66.728[b]	38.4[a]
Zora	2.212[a]	18.586[c]	32.557[c]	37.1[b]
N Amount (B)				
N105	1.946[a]	39.520[a]	83.737[a]	33.6[b]
N150	2.004[a]	31.283[b]	70.713[b]	32.2[c]
N180	1.877[b]	29.249[c]	54.977[c]	36.5[a]
Control	1.535[c]	21.126[d]	43.963[d]	32.1[c]
Average ± $S\bar{x}$	1.840±0.035	30.295±1.334	63.348±2.926	33.6±0.006
Genotype (A)		*2008*		
Siloking	1.685c	43.038[a]	103.960[a]	29.7[c]
NS Džin	1.383b	50.334[a]	70.536[b]	34.2[b]
Zora	2.040[a]	19.454[b]	32.609[c]	37.5[a]
N Amount (B)				
N105	1.804[a]	54.112[a]	79.558[a]	33.4[b]
N150	1.722[b]	36.833[ab]	83.230[a]	31.4[c]
N180	1.772[ab]	32.576[ab]	61.132[b]	36.7[a]
Control	1.512[c]	26.915[b]	52.218[c]	33.7[b]
Average ± $S\bar{x}$	1.702±0.032	37.609±4.482	69.034±3.206	33.8±0.005
Genotype (A)		*2009*		
Siloking	2.173[b]	45.303[b]	107.680[a]	29.0[c]
NS Džin	1.993[c]	54.779[a]	95.587[b]	35.4[a]
Zora	2.728[a]	18.733[c]	36.821[c]	34.2[b]
N Amount (B)				
N105	2.225[b]	40.361[b]	82.690[a]	35.4[a]
N150	2.622[a]	47.316[a]	84.849[a]	35.0[a]
N180	2.224[b]	48.211[a]	83.521[a]	35.9[a]
Control	2.121[c]	22.530[c]	69.058[b]	25.1[b]
Average ± $S\bar{x}$	2.298±0.043	39.605±1.884	80.029±3.077	32.9±0.006

* Means that columns followed by the same letter are not significantly different according to Fisher's protected LSD values (P=0.05)

Compared to its parent genotypes, the interspecies hybrid *Siloking* had a significantly higher total biomass amount per plant. The leaf weight per stem was highest for Forage Sorghum. Sudan grass formed the highest stems and had the largest leaf portion in the total plant mass. Applied nitrogen fertilizers significantly increased the average mass of stems and the portion of in the total biomass. The effect of used nitrogen in kilograms decreased as the plant nutrition intensity increased, from 1.27g to 0.57g of total biomass in the 180 kg ha^{-1} variety. In the years which had less rainfall, the effect of used nitrogen in kilograms was higher during the vegetation period (first and second).

Table 3 The statistical significance of differences the traits (F test and LSD test)

Traits	Test	2007 G (A)	2007 N (B)	2007 AB	2008 G (A)	2008 N (B)	2008 AB	2009 G (A)	2009 N (B)	2009 AB
Plant	F test	***	***	***	***	***	***	***	***	***
Height	LSD 5%	0.051	0.058	0.099	0.051	0.059	0.102	0.068	0.079	0.133
	1%	0.067	0.078	0.132	0.068	0.079	0.134	0.030	0.104	0.175
Leaves	F test	***	***	***	**	NS	*	***	***	***
Mass	LSD 5%	1.144	1.320	2.259	20.182	23.304	39.872	1.378	1.591	2.722
	1%	1.514	1.748	2.974	26.714	30.847	52.484	1.824	2.106	3.583
Stem	F test	***	***	***	***	***	***	***	***	***
Mass	LSD 5%	2.429	2.805	4.798	4.572	5.280	9.033	2.966	3.424	5.859
	1%	3.215	3.712	6.316	6.052	6.988	11.891	3.925	4.533	7.712
Leaves	F test	***	***	***	***	***	***	***	***	***
Portion	LSD 5%	0.009	0.011	0.018	0.011	0.013	0.022	0.008	0.009	0.016
	1%	0.012	0.014	0.024	0.015	0.017	0.030	0.011	0.012	0.021

G (genotype), N (nitrogene) ^{NS}=P>0.05 *=P<0.05 **=P<0.01 ***=P<0.001

Pearson's correlation coefficient indicates that the there is a statistically significant positive correlation between leaf mass and stem mass. There is also a statistically significant negative dependence between stem mass and stem height. On the other hand, there is no statistically significant correlation between leaf mass, stem height and leaf portion, (p>0.05) as shown in Table 4.

Table 4 Correlation matrix of the observed traits (average of 2007-2009)

	Stem height	Leaf mass	Stem mass	Leaf portion
Stem height	-	-0.087^{NS}	-0,180**	0,118*
Leaf mass		-	0,718**	0,097^{NS}
Stem mass			-	-0,549**
Leaf portion				-

^{NS}=P>0.05 *=P<0.05 **=P<0.01

In years with less rainfall (2007 and 2008) the highest yield of total plant biomass was obtained with 105 kg ha^{-1} of nitrogen use. In 2009, when the rainfall layout was more favorable, the optimal plant nutrition was achieved by using with

150 kg ha^{-1}. Further increase of the nitrogen amount did not have a positive effect on yield of green biomass in the observed genotypes (Tab. 5).

Table 5 Ranking of different amounts of N per year

N dosage	Year 2007		Year 2008		Year 2009	
	D_i	Rank	D_i	Rank	D_i	Rank
control	0	IV	0.1132	IV	0	IV
N105	**2.3199**	**I**	**1.6344**	**I**	1.8333	III
N150	1.6569	II	1.1151	II	**2.4152**	**I**
N180	1.4134	III	0.9421	III	2.2577	II

Previous research results of the impact of increasing nitrogen amounts on Forage Sorghum yield components showed that abundant nitrogen nutrition reduces the productive characteristics of these plants (MITROVIĆ, 1998, ERIĆ and ĆUPINA, 2001). The previous study which had dealt with this issue indicated that the effect of nitrogen nutrition of plants also depends on the swath time, so that if the plants are mowed earlier, the nitrogen utilization is lower (OSTOJIĆ, 1992). These surveys included samples of fresh biomass of three varieties of Forage Sorghum that are widely used in the South-Eastern Balkans. The subject of this study were samples of fresh biomass (leaves and stem), selected by a completely randomized block system. The homogeneity of the samples investigated during the three-year study of the tested factors has allowed the obtained results to be presented as average values. However, it was desirable to make comparisons between the three cultivars at the stage of plant growth, because better results are obtained if the mowing is done at the time of the technological maturity of the plants (MIRON *et al*., 2007). In addition to energy and the building materials of Forage Sorghum, in earlier investigations of other varieties of this *Sorghum* species, the presence of protective components such as wide range poly-phenols compounds was detected (DYKES and ROONEY, 2006). Some varieties Forage Sorghum have greater nutritive value compared to forage maize (OLIVER *et al.*, 2004). Previous studies dealing with comparative analysis of the forage biomass quality of Forage Sorghum and maize (JOSHUA *et al.,* 2007) and their impact on the lactation of dairy cows, indicate that the to nutritional properties of Forage Sorghum biomass are better because the obtained milk contains a higher milk fat content. The results of this study concerning morphological traits confirm the dependence of genotypes on the intensity of plant nitrogen nutrition. Nitrogen used in plant nutrition positively influenced the increase of total biomass and the leaf share within it. This parameter is of interest to producers of animal feed. Sorghum is a plant with a crafty root system which has a strong suction power and it can easily utilize unused nitrogen salts that were used for feeding pre-seeded crops. The quantity and layout of the rainfall has a significant impact on the effectiveness of nitrogen use. The research of ERIĆ and ĆUPINA (2001) showed that only in conditions of favorable water levels (irrigation of crops after each swath) it can be justified to increase the amount of nitrogen in plant nutrition. The results of these studies indicate that reducing the amount of N use has no harmful effects on yield in relation to the values commonly used in the production of forage mass. Recommendations in terms of investment in this production can be changed with the recommendation for limited irrigation so that the nutrition system conditions are sustainable and profitable. The right choice of genotype can lead to an increase in yield and improve the quality of forage biomass, even in conditions of reduced nitrogen amounts and limited water resources. Future studies should focus on the variable cost of irrigation and better impact assessment of irrigation on the yield and quality. These facts are backed up by the results of previous studies (AVNER *et al*. 2006; MARSALIS *et al*. 2010). In the agricultural environment conditions which are present in the mountain areas of Serbia before the plants tasseling phase, plants reach the first swath height of 100-150 cm. If the water levels are favorable, it is possible to get an additional swath, but the plants will reach a height of 100 cm during the tasseling phase. Sudan grass and Forage Sorghum can replace silage maize (BOŠNJAK and STJEPANOVIĆ. 1976., BACA *et al.* 2008.). As the area of the Western Balkans is increasingly assuming the characteristics of semi-arid climate areas with very dry and hot summers, the growing of silage maize is becoming unsafe due to high sensitivity of these plants to drought the largest water consumption periods. Sorghums are more tolerant toward drought than maize and have recently become more interesting as fodder plants, especially Sudan Grass, which regenerates well in favorable weather conditions and provides two to three swaths per year. The advantage of Sorghums is that the above ground biomass is easily dried and is suitable for silage. The Sorghum biomass is of lower quality than corn biomass. However, as interspecies hybrids have more a higher digestible value of than the original species, they can completely replace corn as the silage crop.

CONCLUSION

The research results of the production traits of Forage Sorghum genotypes, Sudan grass and their interspecies hybrid during intensified nitrogen nutrition showed that the utilization of this element depends on the water levels. Increased amounts of nitrogen in drought conditions have not affected the vegetative growth of plants. When the water level conditions were favorable, the optimal biomass growth was obtained by using 150 kg ha^{-1} of nitrogen. Very good productive characteristics of the interspecies hybrid show that the genotype obtained through selection can be a suitable fodder crop replacement for the currently grown species of the *Sorghum* genus, as well as for maize.

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GENOTIPSKE SPECIFIČNOSTI KRMNOG SIRKA, SUDANSKE TRAVE I INTERSPECIJES HIBRIDA U USLOVIMA INTENZIVNE ISHRANE AZOTOM

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I z v o d

Predmet ove studije su trogodišnja istraživanja (2007, 2008. i 2009) varijabilnosti morfoloških osobina tri genotipa *NS-Džin* (krmni sirak), *Zora* (sudanska trava) i *Siloking* (interspecijes hibrid) u zavisnosti od od upotrebljenih količina azota za dopunsku ishranu biljaka. Za analize visine i mase svežih stabala, mase listova i udela listova u ukupnoj biomasi uzimani su uzorci iz prvog otkosa kada je i efekat upotrebljenih količina azota bio najveći. Rezultati su pokazali da između genotipova postoje značajna variranja u ispitivanim osobinama. Genotip *Siloking* je u sve tri godine dao najveću ukupnu biomasu. Najveća masa listova bila je u genotipa *NS Džin*, dok je u genotipa *Zora* udeo lisne mase bio najveći u trogodišnjem proseku. Efekat upotrebljenog azota zavisio je od vremenskih uslova, odnosno od rasporeda padavina, tako da su u prvoj i drugoj godini optimalne količine bile 105 kg ha^{-1}, a trećoj 150 kg ha^{-1}.

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