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POSTHARVEST RESIDUES FROM GRASS SEED CROPS FOR BIOENERGY

POSLEŽETVENI OSTACI SEMENSKOG USEVA TRAVA ZA BIOENERGIJU

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ABSTRACT

During grass seed production, a large amount of low forage quality biomass has been produced. Tall growing perennial grasses such as tall fescue (Festuca arundinacea L.) and Italian ryegrass (Lolium multiflorum Lam.) can be used as an alternative source for bioenergy production as they can be grown in less cultivated areas, their residues in seed production could be valuable energy source and can be potentially used as a dual purpose crop (bioenergy and forage). In this research, potentials of yearly biomass production of two important forage grasses grown for seed (Italian ryegrass and tall fescue) varying modes of sowing and nitrogen fertilisation were shown. As a byproduct, postharvest residues of Italian ryegrass reached to 8.8 t/ha in the Mačva region in favourable weather conditions, during 4-year production, while tall fescue reached in southern Banat 10.6 t/ha in the first and 15.1 t/ha in the second year of production.

***Key words**: bioenergy, biomass, grass, seed crop.*

REZIME

Pri proizvodnji semena trava se stvara velika količina biomase koja je slabijeg kvaliteta za ishranu domaćih životinja, ali može biti pogodna za korišćenje kao izvor energije biljnog porekla. Na primeru gajenja dve travne vrste, italijanskog ljulja tokom 4 godine (2003-2006) i visokog vijuka tokom 2 godine (2014-2015) za seme, kroz različite mere agrotehnike (varirajuće načine setve i đubrenja azotom) su prikazani potencijali godišnje produkcije biomase. U skladu sa zemljištem i osobinama trava su primenjeni sledeći međuredni razmaci: 20, 40 i 60 cm za italijanski ljulj i 15, 30, 45 i 60 cm za visoki vijuk, setvene norme od 5, 10, 15 i 20 kg/ha za obe vrste i prolećna prihrana sa 0 i 75 kg/ha N visokog vijuka i 0, 50, 100 i 150 kg/ha kod italijanskog ljulja. Italijanski ljulj je tokom 4 godine ispitivanja na području Mačve imao maksimalni prinos od 8,8 t/ha iz dva otkosa, u prvoj godini proizvodnje semena, pri povoljnim meteorološkim uslovima. Visoki vijuk je u prvoj godini proizvodnje semena u uslovima južnog Banata ostvario maksimalno 10,6 t/ha iz dva otkosa, pri najvećem međurednom rastojanju gajenja (60 cm), kao i 15,1 t/ha u drugoj godini na istom međurednom rastojanju. Prinosi biomase trava ostvareni uz skromnu agrotehniku, u sklopu proizvodnje semena trava, ukazuju na značajan potencijal za proizvodnju bioenergije.

***Ključne reči**: bioenergija, biomasa, semenski usev, trava.*

INTRODUCTION

The EU Energy policy to 2050 states that one of the most prominent energy policy priorities in the European Union is energy production from renewable energy sources, but the type of bioenergy depends on the geographical position of the country and the environmental, economic, sociological and political conditions. The most appropriate raw material for bioenergy production is biomass, and demand for biomass will increase (*Bentsen and Felby, 2012*). Biomass is an abundant and renewable source of energy and its use for that purpose would diversify the energy supply and reduce dependency on fossil fuels. Furthermore biomass production may create additional jobs for the local economy in rural areas (*Rancane et al., 2014*). Biomass yield and quality are the indicators which determine possible energy yield of biomass per unit and an optional species of plants for energy conversion (*Pociene et al., 2013*). Republic of Serbia consumes the amount of fuels equivalent to 15 million tons of oil per year (Mtoe). At the same time, the potential of the renewable energy sources is about 3.5 Mtoe/year. The main renewable source is biomass, with its potential of about 2.6 Mtoe/year, and 60 % of the biomass source is agricultural biomass (*Dakić et al., 2009*).

Many studies have been conducted on a wide diversity of plants, but there is no consensus regarding the crops that would be the most appropriate for bioenergy. It has been suggested that lignocellulosic crops will be a key component of future feedstock, although many unknowns remain in terms of the yield potentials of different crop species in a wide range of soil and climate conditions, on marginal lands or in the face of climate change (*Gabrielle et al., 2014*). Recently, increased attention has been focused on perennial grasses as a raw material for bioenergy production in Europe and the USA (*Ceotto, 2008; Jasinskas et al., 2008; Prochnow et al., 2009; Kanapeckas et al., 2011; Song et al., 2015*). Perennial grasses may provide a renewable source of biomass for energy production since they have many advantages including reduced cost of establishment and cultivation; relatively high yield potential on land not suitable for annual crops; soil and water conservation; increased carbon sequestration; and wildlife habitat conservation (*McLaughlin et al., 2002*). Besides contributing to the reduction of anthropogenic carbon dioxide (CO_2) emissions, these alternative biomass materials show other ecological benefits. They prevent soil erosion and require limited soil management and a low demand for nutrient inputs (*Fournel et al., 2015*).

Different requirements of biomass quality are for biogas production and solid fuels, but there is one, which is common for all bioenergy sources, namely biomass yield (*Prochnow et al., 2009*). In addition, low moisture content, low levels of ash and alkali metals, and high fiber content are the desirable features of a crop to be used as a source of bioenergy (*Tahir et al., 2011*). To be a potential perennial energy crop, a perennial species should be native, have high biomass yield potential, be harvested with typical farm equipment, and exhibit positive environmental attributes. Grass biomass is a suitable feedstock for bioenergy production, thus the variation of energy value of tall fescue ranged from 10.87 to 14.67 MJ/kg DM (*Tilvikiene et al., 2016*). Calorific value in above-ground biomass of Italian ryegrass during 3 year studies was in average 18.05 MJ/kg (*Fuksa et al., 2013*).

During grass seed production, a large amount of low forage quality biomass has been produced. Two perennial grasses, tall fescue (*Festuca arundinacea* Schreb.) and Italian ryegrass (*Lolium multiflorum* Lam.) were selected for evaluation in Serbian conditions. Tall fescue produces a high and stable biomass yield, but recently, tall fescue has been started to be used for bioenergy (*Kanapeckas et al., 2011*). Italian ryegrass is one of the most important forage grasses in Serbia because of its high nutritive value and high biomass production *(Simić et al., 2009a)*. Different growing technologies were used to evaluate the influence of fertilisation and sowing tecniques (different seeding rates and inter-row spacings) on the biomass productivity and energy potential of those grass species.

The goal of the research was enhancement of valuable producents biomass productivity and quality by agrotechnological implements making qualitative biomass composition which have influence for bioenergy parameters and DM yields. In this study, tall fescue and Italian ryegrass as seed crops were chosen for field experiments to determine the proper management system and fertilisation level of N for biomass production.

MATERIAL AND METHOD

The studies were conducted for 4 consecutive years, between 2002 and 2006 for Italian ryegrass seed crop and for 2 consecutive years (2013-2015) for tall fescue seed crop. Italian ryegrass cv. Tetraflorum and tall fescue cv. K-20 were sown under agroecological conditions of Mačva (Štitar, N 44º 47´; E 19º 35´, 83 m asl) and Banat (Banatsko Novo Selo, N 44°59′; E 20°41′, 105 m asl). A three-factorial trial (sowing rates x inter row spacing x fertilisation rates) was set up as a random block design on 10 m^2 plots (2.5 x 4 m) and the data on experimental design are shown in table 1. Italian ryegrass was planted each autumn prior to the preceding summer seed harvest, while tall fescue was planted at the beginning of the experiment (autumn 2013) and biometric measurements were made in the first and second production years.

Table 1. Details of the experiment

Treatment	Štitar	B.N. Selo
Inter row spacing (cm)	20 40 60	15 30 45 60
Seeding rate (kg/ha)	5 10 15 20	5 10 15 20
Spring nitrogen application (kg/ha N)	0 50 100 150	0 75

Seeds from the primary growth of both species were harvested in the first production year after establishment for Italian ryegrass and in the first/second year of tall fescue growth. Large amount of produced grass biomass (straw) was measured after seed harvest. Data were analyzed using appropriate statistical analyses (e.g. ANOVA) and Statistica v.8.0 software. The level of significance ($P \geq 0.05$) was determined by LSD testing.

Soils in the experimental areas were humofluvisol, with rinsed limestone (Štitar) and carbonate chernozem (B. N. Selo) and the main characteristics of the soil are shown in the table 2. Spring nutrition with calcium ammonium nitrate (CAN) was carried out every spring of experimental years.

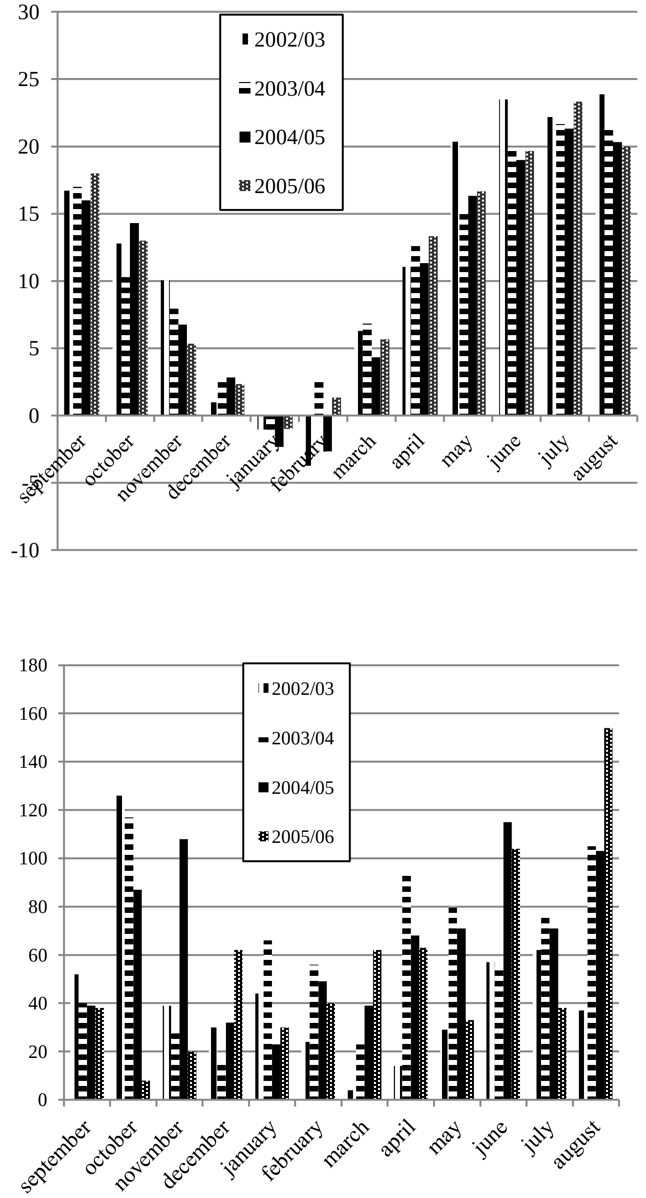
Table 2. Chemical properties of the soil

Depth 0-30	pH in KCl	$CaCO_3$ %	Total N	Humus %	AL-P_2O_5 mg/100g	AL-K_2O mg/100g
Štitar	5.25	0.36	0.197	2.54	3.0	15.1
B. N. Selo	7.30	10.32	0.260	3.35	22.1	19.7

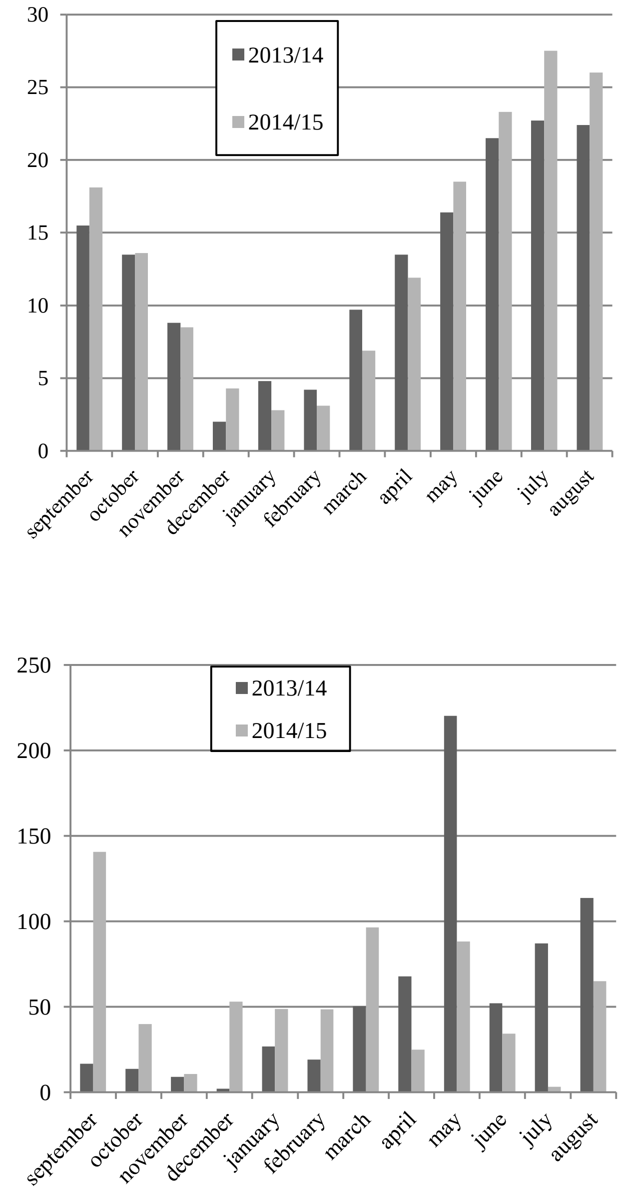
RESULTS AND DISCUSSION

Monthly precipitation and temperature during the 4 years ie. 2 years of the studies varied widely. Accumulated precipitation during the spring of 2003 was deficient for Italian ryegrass (Figure 1). The critical period for both grasses growth was April-June. During the spring of 2004 and 2005, precipitation was abundant, while the spring of 2006 had moderate to normal precipitation. The winter of 2006 was characterized by high precipitation and longevity of snow cover, resulting in some ryegrass injury and loss, especially in 40 cm row spacing plots. During 2014 and 2015 temperature regime was similar, but May of 2014 was extremely humid with precipitations of 220 mm.

The aim of the present study was to estimate the potential of tall fescue and Italian ryegrass biomass grown for seed production in relation to the sowing management and mineral nitrogen fertilisation. The yield of plant species studied varied greatly because of different environmental condition during vegetation seasons. Grass seed crops are especially susceptible on rainfalls and temperatures during spring growth (*Griffith et al., 1997*). The yield reduction of Italian ryegrass in the first year of production was mostly influenced by unequal rainfall distribution (Fig.1), there was insufficient rainfall in April and May. Similar to Italian ryegrass seed production, where climatic conditions, temperature and precipitation, played a major role in determining the level of influence of seeding rate and inter-row spacing on Italian ryegrass seed yield (*Simić et al., 2009b*), ryegrass biomass production also depends on the climatic conditions during vegetation season. Reduced biomass yield, which occurred in 2003, as compared to other years, was most likely the result of a spring rainfall shortage and a significant effect of the treatments. The lowest average straw yield was observed in 2003, while the highest was in 2005, with a difference of more than 400 % (1.81 and 8.33 kg/ha in 2003 and 2005, respectively, table 3). Straw yield in 2004 was also high, similar to 2005, while in 2006 year unfavourable environmental conditions halved straw yield in comparison to favourable years. The spring drought in 2003 affected tiller characteristics, and consequently, final straw yield. Straw yields were impacted by sowing techniques all 4 years in Italian ryegrass ie. 2 years in tall fescue, marked, however, by an opposite impact in arid and humid weather conditions.



Precipitations and air temperatures during four consecutive vegetation seasons of Italian ryegrass seed crop



Precipitations and air temperatures during two consecutive vegetation seasons of tall fescue seed crop

Fig. 1. Weather conditions during experiments

Higher seeding rates (20 kg/ha) and spring nitrogen application (75 kg/ha) with wide inter-row spacing (60 cm) could improve tall fescue biomass yield (table 4). *Moyer et al. (1995)* reported that fertiliser tests on tall fescue in the USA showed a yield increase of 69 % when nitrogen fertiliser level was increased from 13 kg/ha to 168 kg/ha. Shoot dry mass accumulation was strongly influenced by stand establishment throughout our experiments, and the biomass yield response to density was more consistent than that of fertilisation rate.

The annual biomass yield was higher in fertilised tall fescue sward compared to non fertilised, while Italian ryegrass did not have consistent response to N application. The results of the present study support the use of a relatively low nitrogen rate for Italian ryegrass biomass production, similar to findings *Simić et al., (2010)* for ryegrass seed production.

Tall fescue plant material has mineral concentration of approximately 9-10 % ash, 2-3 % silicon dioxide (SiO_2), 2.5 % nitrogen, 100 mg/kg iron, 60-70 mg/kg manganese and 5-6 mg/kg copper (*Pahkala et al., 1994*). The mineral concentrations were highest in leaf blades *(Pahkala et al., 2000)*. By removing the leaf blades, the ash and mineral contents would decrease considerably and at the same time, the relative fibre content could increase, thus increasing the value of plant material for industrial use. Also, same authors recommend, beside suitable plant species, suitable harvest time and using only the plant parts (stem) which contain low amounts of minerals.

In the study *Pahkala et al., (2000)*, the highest stem yield was given by reed canary grass when harvested in spring as a senescent crop and the yield level remained constant for at least 6 years. There is opportunity to use grass seed crop for many years taking into account that grass straw has proportionally higher share of stem in comparison to leaf.

Table 3. The effect of inter-row spacing (cm), seeding rate (kg/ha) and spring N application (kg/ha) on grass biomass (straw) agroecological conditions of Mačva

	Štitar (Italian ryegrass)			
Interrow spacing	2003	2004	2005	2005
20	2.10[a*]	8.01[b]	7.70[a]	4.42[a]
40	1.82[b]	8.63[a]	7.09[b]	2.54[b]
60	1.50[c]	8.56[a]	6.39[c]	4.66[a]
Seeding rate				
5	0.85[d]	7.52[c]	5.87[c]	3.28[b]
10	1.48[c]	8.24[b]	6.90[b]	4.00[a]
15	2.31[b]	8.77[a]	7.72[a]	3.90[a]
20	2.58[a]	8.81[a]	7.74[a]	4.33[a]
Fertilisation rate				
0	1.73[b]	8.12[b]	6.73[b]	2.66[c]
50	1.94[a]	8.47[a]	7.11[ab]	3.87[b]
100	1.64[b]	8.43[a]	7.51[a]	4.41[a]
150	1.91[a]	8.32a	6.88[b]	4.55[a]
Average	1.81	8.33	7.06	3.87

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

Our experimental findings suggest that biomass yield differed significantly between grass species, similar to findings *Tilvikiene et al. (2012)*. Tall fescue has highest biomass productivity per area among three examined grasses (cocksfoot and reed canary grass), cut four times per season. *Yasuda et al. (2015)* reported that Italian ryegrass is suitable lignocellulosic raw material with high energy crops for bioethanol production. They examined ryegrass bioethanol production from Italian ryegrass through a low moisture anhydrous ammonia pretreatment and simultaneous saccharification and co-fermentation.

Table 4. The effect of inter-row spacing (cm), seeding rate (kg/ha) and spring N application (kg/ha) on grass biomass (straw) agroecological conditions of Banat

	Banatsko Novo Selo (Tall fescue)	
Interrow spacing	**2014**	**2015**
15	6.91[c]	13.60[b]
30	7.18[c]	11.07[c]
45	7.70[b]	11.35[c]
60	10.6[a]	15.13[a]
Seeding rate		
5	6.86[d]	12.08[c]
10	7.67[c]	12.88[b]
15	8.70[b]	11.79[c]
20	9.15[a]	14.40[a]
Fertilisation rate		
0	7.83[b]	11.83[b]
75	8.59[a]	13.92[a]
Average	**8.09**	**12.79**

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

It should be pointed that tall fescue yield response to growing technology in our research was consistent in both production years notwithstanding they were extremely different according to weather conditions. Also, tall fescue response was more consistent than Italian ryegrass to crop management. It means that Italian ryegrass is more sensitive to environmental conditions of vegetation season.

CONCLUSION

The results of a two-year experiment for tall fescue and a four-year experiment for Italian ryegrass suggest that the biomass yield and energy potential depend on grass species and growing technology. It can be concluded that these grass species react differently to climatic conditions and applied treatments. Biomass yield in the experimental periods of use varied considerably depending on the fertiliser, sowing density and species, ranging up to 8.8 t/ha for Italian ryegrass and 15.1 t/ha for tall fescue. Applied fertiliser rate provided a significant increase of fescue DMY. In the 2[nd] year of sward use the biomass yield of tall fescue and fertiliser efficiency in two-harvest regime was similar to the first year. The highest biomass yield and energy potential was achieved for tall fescue harvested twice per season and sown on 60 cm between rows, with 75 kg/ha N and 20 kg/ha seeding rate. The results of the ryegrass seed production indicates that in order to maximize straw yield in the first production year a high seeding rate is preferable (15-20 kg/ha) and low spring application rates. Relatively higher biomass yield was provided by tall fescue.

It is possible to improve the raw material for fuel (energy) production by choosing a suitable plant species, such as tall fescue and Italian ryegrass, with a special focus on the plant parts which contain low amounts of minerals.

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