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INTERCROPPING OF SOYBEAN AND PROSO MILLET FOR BIOMASS PRODUCTION

ZDRUŽIVANJE USEVA PROSA I SOJE ZA PROIZVODNJU BIOMASE

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ABSTRACT

Sustainable agriculture considers production of high quality food and feed with minimal impact on environment. Intercropping is one of the most efficient ways to produce valuable biomass for animal feed rich in nutrients. Intercrop combinations: alternating rows of soybean and proso millet (S-M), alternating strips with 2 rows of soybean and 2 rows of millet (SS-MM-SS) and alternating strips with 2 rows of soybean and 4 rows of millet (SS-MMMM-SS); single crop of soybean and single crop of proso millet were tested. The effect of bio-fertilizer Coveron was also followed. Aboveground biomass was harvested and land equivalent ratio (LER), as well as leaf area index (LAI) was determined. All intercropping combinations increased LAI of soybean when compared to monocrop, to 43% and 84% in SS-MM-SS combination with and without Coveron, respectively. Coveron slightly increased LAI. The highest values of biomass yield were obtained in S-M intercrop for soybean (39% and 42% higher in relation to monocrop, in combination with and without Coveron, respectively) and in monocrop for proso millet. Nevertheless, the highest LER value was obtained for SS-MM-SS combination without Coveron (1.12). In intercrops treated with Coveron slightly lower LER values were obtained for S-M and SS-MMMM-SS combination (0.97 and 0.98, respectively). Irrespective to sowing way, results indicate that 1:1 ratio of soybean and proso millet in intercrop (S-M and SS-MM-SS combinations) is the most promising way to achieve high biomass yield.

Key words: intercropping, biomass, land equivalent ratio (LER), leaf area index (LAI)

REZIME

Održiva poljoprivreda obuhvata proizvodnju visoko-kvalitetne hrane i hraniva sa minimalnim uticajem na životnu sredinu. Zdrživanje useva je jedan od najefikasnijih načina za dobijanje biomase visoke hranljive vrednosti. Ispitivane su sledeće kombinacije združenih useva: naizmenični redovi soje i prosa (S-M), naizmenične trake 2 reda soje i 2 reda prosa (SS-MM-SS) i naizmenične trake 2 reda soje i 4 reda prosa (SS-MMMM-SS); samostalni usev soje i samostalni usev prosa. Praćen je takođe i uticaj mikrobiološkog đubriva Coveron. Nadzemna biomasa je sakupljena i odnos ekvivalenata zemljišta (LER) kao i indeks lisne površine (LAI) su određeni. Sve kombinacije združenih useva utiču na povećanje indeksa lisne površine soje u odnosu na samostalni usev, do 43% i 84% u SS-MM-SS kombinaciji sa i bez Coveron-a. Coveron neznatno utiče na povećanje LAI, u proseku. Najviši prinos biomase je postignut u S-M kombinaciji za soju (39% i 42% viša u odnosu na čisti usev, u kombinaciji sa i bez Coveron-a) i u čistom usevu za proso. Ipak, najveća vrednost LER-a je dobijena za SS-MM-SS kombinaciju bez Coveron-a (1.12). Kod združenih useva tretiranih Coveron-om, slične vrednosti LER-a su dobijene za S-M i SS-MMMM-SS kombinacije (0.97 i 0.98). Bez obzira na način setve, rezultati pokazuju da je 1:1 odnos soje i prosa u združenim usevima (S-M i SS-MM-SS kombinacije) najperspektivniji način da se postignu visoki prinosi biomase.

Ključne reči: združeni usevi, biomasa, odnos ekvivalenata zemljišta (LER), indeks lisne površine (LAI)

INTRODUCTION

Intensive agriculture systems are often based on productivity and profitability, demanding high inputs to achieve high yields. Such systems negatively impact environment regarding soil and water, increasing chemical contamination and decreasing biodiversity (Malézieux *et al.*, 2009). Sustainable agriculture is economically convenient type of agriculture which is in balance with the environment. The purpose of sustainable agriculture is efficient use of resources that improve security and stability of food and feed (Mousavi and Eskandari, 2011). Various practices are implied to follow principles of this agro-ecology type such as intercropping, crop rotations, cover cropping, etc (Duchene *et al.*, 2017). Intercropping is one of the most efficient ways to produce valuable biomass for animal feed, rich in nutrients (Iqbal *et al.*, 2018). Previous studies demonstrated advantages of intercropping regarding biodiversity, land-use efficiency, soil quality, nutrient-use efficiency and productivity. Intercropping

envelops planting two or more crops species simultaneously in a same area during a same growing season and can be divided into four groups: row, mixed, strip and relay intercropping (Du *et al.*, 2018). It is well known that an advance of intercropping depends on spatial arrangements and types of plants used in it. The performance of one crop can significantly differ when it grows as intercrop when compared within sole crop (Nelson and Robichaux, 1997; Esmaeili *et al.*, 2011). Cereals and legumes are recognized as favourable combination for intercropping because of improved resources utilization (Duchene *et al.*, 2017). What is more, legumes are N-fixing plants and are important source of N (proteins) for both humans and livestock (Amanullah *et al.*, 2016). On the other side, cereals contain low protein content but still are widespread used in livestock nutrition as a starchy component due to high dry matter yield and low cost. Combination of these characteristics of cereals and legumes can be good basis to get economically profitable high quality forage. According to Eskandari *et al.* (2009), potential

benefits can refer to productivity, soil fertility, forage quality and reduced damage caused by pests, diseases and weeds.

Millets belongs to the most suitable crops for sustaining agriculture because they are grown under harsh conditions with negligible yield losses. Also, growing under low-input agricultural conditions and on the marginal lands are another advantages of this crop. In recent years, millet becomes important cereal for intercrop due to its wide adaptability to various agro-ecological conditions (Habiyaemye et al., 2017). Proso millet (*Panicum miliaceum*) belongs to the group of minor millet and it is the one of the oldest cultivated crops. It contains high-quality proteins and it is more valuable than other cereals which justify its all-wider use (Kalinová, 2007).

Soybean (*Glycine max*) is a one of the most important legume crop in the world and it is also called „Golden bean” or „Miracle crop”, based on its multiple uses. Its importance for sustainable agriculture is reflected in the ability to reduce soil carbon and nitrogen losses thus improving soil fertility and yields. Also, the ability of soybean to accumulate nitrogen enabled it to become a plant with high nutritive value for food and feed. The highest protein content (40%), richness in oil, vitamins and minerals makes soybean being harmonized crop for combining with cereals (Du et al., 2018; Manjunath and Salakinkop, 2017).

Possible benefits of intercrop versus sole crop on biomass production can be measured on different ways (Jahanzad et al., 2015). In this paper the productivity of two crops grown as intercrop and sole crop was evaluated, simultaneously testing the influence of bio-fertilizer on them. To evaluate these benefits, we used three parameters in this study: total biomass yield, land equivalent ratio (LER) and leaf area index (LAI).

MATERIAL AND METHOD

The experiment was conducted in experimental field of the Maize Research Institute Zemun Polje, in the vicinity of Belgrade (44°52'N 20°20'E), during 2018 vegetative season. Variety of proso millet (*Panicum miliaceum*) (Biserka) obtained from Institute of Field and Vegetable Crops, Serbia, and soybean (*Glycine max* (L.)) (Selena) obtained from Maize Research Institute Zemun Polje, Serbia, were used in experiment. Tested intercrop combinations were: alternating rows of soybean and millet with 50 cm space between rows (S-M), alternating strips with 2 rows of soybean at 50 cm inter-row distance and 2 rows of millet with 25 cm on inter-row distance (SS-MM-SS) and alternating strips with 2 rows of soybean and 50 cm space between them and 4 rows of millet with 25 cm between them (SS-MMMM-SS); sole crop of soybean (50 cm space between rows) and sole crop of proso millet (25 cm space between rows). The effect of bio-fertilizer Coveron (containing *Glomus sp.* and *Trichoderma*; Italpollina, Italy) was also followed. Sowing was performed at the beginning of May and experiment was managed in dryland farming without fertilization or application of any other agrochemical. Weeds were removed by hoeing, two times during vegetation. At the beginning of August, aboveground biomass was harvested, total biomass yield was measured (t/ha) and land equivalent ratio (LER), as well as leaf area index (LAI) was determined. LER was calculated according to the formula proposed by Mead and Willey (1980). For the calculation of LAI, leaf area was recorded by LI-COR LI-

3100 Area Meter, Lincoln, Nebraska USA. Leaf area index was calculated out by dividing the leaf area per plant by land surface area occupied by the plant (Manjunath and Salakinkop, 2017).

All obtained results are analysed using analysis of variance (ANOVA) based on two-factorial randomised complete block design and treatments means are compared by the Fisher's least significant difference (LSD) test at $p = 0.05$.

RESULTS AND DISCUSSION

The presented results for soybean (Table 1) show that bio-fertilizer slightly increased average values of LAI and biomass yield, while intercropping significantly influenced the same parameters. Similar effect of bio-fertilizer on LAI has been proved for corn-soybean intercropping (Baghdadi et al., n.d.). All intercropping combinations increased LAI of soybean when compared to monocrop, significantly in SS-MM-SS combination, to 43% and 84% with and without Coveron, respectively. It is in contrast with results obtained by Manjunath and Salakinkop (2017), where sole crop gave the highest LAI

Table 1. Effect of different intercrop combinations and bio-fertiliser on biomass yield and leaf area index of soybean

Soybean cropping system	LAI (cm ² /cm ²)			Total yield (t/ha)		
	F	FØ	Average	F	FØ	Average
Sole crop	9.20	8.00	8.60	52.66	49.66	51.16
S-M	11.50	11.27	11.38	73.25	70.66	71.96
SS-MM-SS	13.14	14.70	13.92	63.25	70.37	66.81
SS-MMMM-SS	11.87	10.69	11.28	56.01	52.18	54.09
Average	11.43	11.16	11.30	61.29	60.72	61.01
LSD ($p = 0.05$)	F 2.95, IC 2.30, F x IC 2.40			F 11.55, IC 7.60, F x IC 7.79		

[‡]S - soybean, M - proso millet, IC - intercropping, F - bio-fertilizer, LAI - leaf area index

value. Likewise, intercropping expressed a significant effect on average biomass yield, emphasizing S-M combination as the most promising. In relation to monocrop, this combination provided 39% and 42% higher yield (with and without Coveron, respectively). Consequently, in regard to soybean, the highest values of LAI and total yield have been ensured from 1:1 ratio of soybean and millet intercrop. Similar trend for influence of bio-fertilizer on LAI and total yield values was noticed for proso millet, too (Table 2). In regard to LAI, higher average value was obtained from treatment with Coveron (19%), while in terms of total yield slightly higher value was obtained for variant without bio-fertilizer (2%). On the other hand, intercropping showed significant difference in respect of LAI and total yield. The highest LAI value was recorded in SS-MM-SS combination, while the highest value of total yield was for monocrop. However, Manjunath and Salakinkop (2017) showed that the

Table 2. Effect of different intercrop combinations and bio-fertiliser on biomass yield and leaf area index of proso millet

Proso millet cropping system	LAI (cm ² /cm ²)			Total yield (t/ha)		
	F	FØ	Average	F	FØ	Average
Sole crop	14.95	8.51	11.73	25.35	25.29	25.32
S-M	7.01	6.68	6.84	15.52	14.60	15.06
SS-MM-SS	12.78	14.01	13.40	14.14	17.62	15.88
SS-MMMM-SS	10.71	9.01	9.86	22.84	22.17	22.51
Average	11.36	9.55	10.46	19.47	19.92	19.69
LSD ($p = 0.05$)	F 3.28, IC 2.39, F x IC 1.68			F 5.89, IC 3.95, F x IC 4.13		

[‡]S - soybean, M - proso millet, IC - intercropping, F - bio-fertilizer, LAI - leaf area index

highest LAI value was for millet sole crop. In experiment with mung bean, proso millet had a higher value of LAI as intercrop compared to monocrop (Gong et al., 2018). These different results are in accordance with variation of LAI values in our experiment and can be explained by different location and climatic conditions. Mutual interactions of treatments significantly affected biomass yield of proso millet in sole crop and in SS-MMMM-SS intercrop. Therefore, these values are significantly higher than others one. As far as LAI, greater values were acquired in sole crop treated with fertilizer and in both SS-MM-SS intercrop combinations. These results indicate that proso millet have been suppressed by soybean in SS-MM-SS combination, which was reflected on the biomass yield. Still, more suitable parameter to compare yields is LER because it expresses yield advantages comparing intercrop with sole crops (Mead and Willey, 1980). The highest LER value was obtained for SS-MM-SS combination without Coveron (1.12) with significant difference at the level of 95% (Table 3). This ratio proved to be advantageous with others cereals and legumes, too (Amanullah et al., 2016; Esmaili et al., 2011). However, this value is not as large as compared to the values obtained by Manjunath and Salakinkop (2017) where soybean and millet intercropping gave better results, what could be due to various ratio of soybean and millet (4S:2M). In intercrops treated with Coveron slightly lower LER values, comparing to monocrop, were obtained for S-M and SS-MMMM-SS combination (0.97 and 0.98, respectively). Furthermore, mutual interaction of intercropping and bio-fertilizer was the main factor responsible for significant variations of LER.

Table 3. Effect of different intercrop combinations and bio-fertiliser on land equivalent ratio (LER)

Intercropping system	LER		
	F	FØ	Average
S-M	0.97	0.96	0.96
SS-MM-SS	0.94	1.12	1.03
SS-MMMM-SS	0.98	0.95	0.97
Average	0.96	1.01	0.99
LSD ($p = 0.05$)	F 0.13,	IC 0.13,	F x IC 0.13

[†]S - soybean, M - proso millet, IC - intercropping, F - bio-fertilizer

CONCLUSION

Based on obtained results, it can be concluded that the biomass yield of proso millet and soybean can be improved by adopting certain intercropping combinations. Regarding to LAI, the most suitable combination is proved to be SS-MM-SS intercrop. Contrary to expectations, bio-fertilizer didn't significantly influenced results. Moreover, bio-fertilizer showed negative effect on intercrop yield - LER. When proso millet and soybean were intercropped in SS-MM-SS system without fertilizing, the highest LER value was obtained (1.12). Irrespective to sowing way (alternating rows or strips), results indicate that 1:1 ratio of soybean and proso millet in intercrop (S-M and SS-MM-SS combinations) is the most promising way to achieve high biomass yield.

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