



The Influence of Row Spacing on Yield and Quality Levels of Sainfoin (*Onobrychis viciifolia* Scop.) Seed in Agroecological Conditions of South Serbia

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Abstract

In agroecological conditions of South Serbia, the influence that row spacing has on sainfoin seeds yield and quality was examined. The *Makedonka* cultivar was sown at the row spacing of 20, 40 and 60 cm. The three year average seed yield of 483.5 kg ha⁻¹ was made. The first year yielded the lowest (256.1 kg ha⁻¹), whereas the highest was in the third and last year of research (649.0 kg ha⁻¹). With respect to the row spacing, the highest yields were achieved at 40 cm (514.3 kg ha⁻¹), and the lowest at 20 cm (428.7 kg ha⁻¹). The row spacing had a significant effect on the quality of the seed. The highest germination energy (86.7%), seed germination (90.4%), 1000 kernel weight (25.2 g), along with the lowest hard share of hard kernels (3.5 %) were obtained at 60 cm of row spacing.

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Introduction

Sainfoin is a very old culture that was also considered to have medicinal properties in ancient times. It was first grown in Mediterranean, a few thousand years ago. According to Delgado (2008), it first began to serve as fodder in the Middle Ages, in France. It soon spread throughout the entire Europe, and later on the world, as well. Today, it is grown on larger areas in moderately warm parts of Europe, Mediterranean countries, Asia, Russia, and west parts of North America (Smoliak *et al.*, 1972). In Serbia, it is grown less, and mostly in southern and south-eastern regions of the country (Vučković, 1999).

In arid, as in semi-arid, regions, on shallow, rocky and poor lands, red clover and alfalfa cannot even compare to sainfoin. In conditions like these, sainfoin is almost the only culture that can be grown successfully. It features a strong root system, which it uses to permeate the soil, so it can successfully be used as a protector of erosion. Thanks to the symbiosis with nitrogen fixating bacteria, sainfoin takes in significant amounts of nitrogen and provides the soil with the feed for the next crop (Kral and Delaney, 1982). Compared to alfalfa and red clover, sainfoin suffers less damage from dodder. It's also more resistant to pests than alfalfa, especially to the alfalfa weevil (*Hypera postica*), which causes a decrease in production (Morill *et al.*, 1998, Mohajer *et al.*, 2011). Sainfoin does not cause bloating in cattle, so biomass can therefore be used completely safely (Howarth *et al.*, 1978). It can be used for both grazing and mowing, and it is also resistant to trampling. It yields great results if sown with grasses as well as in pure sowing. It's as significant as honey plants.

Despite all the mentioned positive characteristics and yields of dry matter of 12-14 t ha⁻¹ in agroecological conditions of Serbia (Ćupina *et al.*, 1999, 2010), sainfoin does not take on significant areas. The main reason for such state is the advantage that alfalfa has over sainfoin (high yield, quality) when it comes to cultivating, but also the lack of profitable seed production, i.e. low seed yields (Stevović *et al.*, 2012). For good crops establishment, large amounts of seeds

(pods) are necessary. That is why the increase in production and seed yields of sainfoin is of significant importance for enlarging areas under this crop. Seed production of perennial legumes largely depends on climatic conditions, especially precipitation, temperature and evaporation levels during the vegetative season. Besides the climatic factors, numerous studies suggest that the method and density of sowing have a significant effect on seed (pods) yields of sainfoin. Sowing at 20 cm of in between row spacing, using larger amounts of seeds, results in higher yields of the sainfoin seed (Vuckovic *et al.*, 1997, Ivanovski *et al.*, 1998 and Martinello, 1998). Contrary to this, high levels of good quality seed yields are obtained with lesser plant density at higher row spacing distance of around 50-80 cm (Bratu *et al.*, 1981, Manea 1985, Altın and Tuna, 1996, Stevović *et al.*, 2012). Next to the yield levels, chosen sowing method and density have a big influence on the quality of the sainfoin seed, as well. Sowing sainfoin at greater row spacing regularly yields better quality seeds, primarily larger 1000 kernels weight and germination rate (Stanisavljevic *et al.*, 2004). Significant effect on the seed quality also comes from the ecological conditions.

The purpose of these studies was to examine the influence of row spacing and growing conditions on yield and quality of the sainfoin seed in agroecological conditions of South Serbia, which would represent a significant contribution to knowing and improving the cultivation, as well as increasing the areas under this important plant.

Material and methods

Plant material

Sainfoin cultivar used is known as *Makedonka*. It belongs to the giant type of cultivars, which flourish and yield seeds in the planting year. Seeds were sown by hand on April 22nd in 2011 at three different row spacing distances: 20, 40 and 60 cm. For sowing at 20 cm of spacing, 150 kg ha⁻¹ of seeds (pods) were used. Sowing at 40 cm of row spacing took 75 kg ha⁻¹, whereas 50 kg ha⁻¹ of seeds were used for sowing at 60 cm spacing distance. The size of the base plot used for

sowing at 20 cm of row spacing (5×1 m) was 5 m², followed by a 6 m² (5×1.2 m) plot used for sowing at 40 cm of row spacing, and a 9 m² (5×1.8 m) plot that was used for the largest row spacing (60 cm). The experiment was set up using the random block system with 4 repetitions.

Measurements

Yield and quality of the seed were determined using the first cut during all three years of research. Sainfoin seed yield was determined at a stage when 70-80% of the pods turned brown. After drying, pounding and sifting operation, the average seed yield was calculated on each plot based on kg ha⁻¹. The seed samples obtained from each plot were used to determine 1000-kernel weight (by measuring the 1000-seed weight in 4 replications), germination rate, germination energy, and proportion of hard kernels in an average sample of 50 g by germinating seeds on filter paper at 20 °C in 4 replications of 100 seeds.

Statistical analysis

Achieved results were processed using the variance analysis method (ANOVA), using SPSS (SPSS !995) and the significances among the obtained values were confirmed using the LSD test. For characteristics of seed quality, the variance coefficient was used (CV).

Soil properties

The examination was taking place on the alluvium soil. In terms of pH values of neutral reaction,

moderate levels of organic matter (2.83%). Soil contains moderate levels of nitrogen (0.14%), and higher levels of phosphorus (18,6 mg/100 gr P₂O₅) and potassium (21,5 mg/100 gr K₂O). The preceding crop was winter wheat.

Weather conditions

Based on the data obtained over multiple years, Nis area is characterized by a long and dry summer period. However, the crop establishment year (2011) endured a very dry spring, which can be seen in low precipitation levels in April (12.5 mm), which caused a slight delay in planting, as well as slower germination rate (table 1).

During 2012, the dry period occurred during seed ripening, which caused somewhat lower yields, as compared to the following year, which was the most suiting one for sainfoin seed production (table 1), due to the adequate distribution and amount of precipitation.

Results and discussion

Seed yields

During the three years of research in agroecological conditions of South Serbia using the *Makedonka* sainfoin cultivar, an average annual seed (pods) yield of 483.5 kg ha⁻¹ was obtained. Not counting the sowing year, in which 256.1 kg ha⁻¹ of average yield was achieved, the following two years (years of full exploitation) yielded an average of 597.2 kg ha⁻¹.

Table 1. Mean monthly temperatures (°C) and total precipitation (mm)- Niš 2011-2013.

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII Aver./ Amou-nt
Temperatures (°C)													
2011	0.6	0.3	6.9	12.5	16.4	21.2	23.5	24.2	21.6	10.7	3.9	3.7	12.2
2012	0.1	-4.0	8.3	13.4	16.5	23.9	26.6	25.0	21.3	14.3	9.7	1.0	13.1
2013	2.8	4.9	6.8	14.1	18.9	20.7	22.9	25.2	17.2	13.9	9.5	1.7	12.7
Amount of precipitation (mm)													
2011	24.6	43.2	30.7	12.4	71.3	42.5	67.6	4.1	38.4	36.7	1.7	38.7	411.9
2012	98.1	61.0	13.5	85.8	162.0	5.9	37.9	10.6	14.7	53.3	8.5	79.9	631.9
2013	43.5	72.4	91.2	39.2	52.1	48.0	20.0	37.6	35.9	67.5	59.1	15.3	581.8

This shows that satisfying sainfoin seed yields can be obtained in the given agroecological conditions (table 2). The results showed that agroecological conditions had a significant effect on the seed yield. The highest

seed yields were achieved in the last year of research (649,0 kg ha⁻¹), which is also the year with best conditions for seed production. During that year, the distribution of precipitation was very favourable,

which resulted in obtaining the highest yields during the research. Not surprisingly, the absolute highest yield (669.1 kg ha⁻¹) was also achieved in 2013, at 40 cm of spacing (table 2). During 2012, the conditions were somewhat less favourable for seed production. The dry period during the ripening caused somewhat lower sainfoin seed yields (545.5 kg ha⁻¹ on avg.). Examining the effect that plant density and row spacing had on the seed yield, Stanisavljevic *et al.* (2004) achieved the average sainfoin seed yield of 201,0 kg ha⁻¹ in the crop establishment year, while the second year averaged 635.0 kg ha⁻¹. Similar to this,

Stevovic *et al.* (2012) obtained the average yield of 179.9 kg ha⁻¹ in the first, 592.0 kg ha⁻¹ in the second, and 579.3 kg ha⁻¹ in their third year of research. Growing sainfoin in conditions without irrigation, Martinelo (1998) obtained the yield of 261 kg ha⁻¹, while the yield was significantly higher (ha 732 kg ha⁻¹) when irrigating until June, and 1554 kg ha⁻¹ when irrigating during the entire vegetation period. Hosainejadmir *et al.* (2011) achieved an average seed yield of 602.2 kg ha⁻¹ by growing 34 populations of sainfoin in irrigation-present conditions, ranging from 453.3 – 737.0 kg ha⁻¹.

Table 2. Effect of row spacing on seed yield of sainfoin (2011-2013).

Row spacing	Seed yield kg ha ⁻¹			Average
	2011	2012	2013	
20 cm	241.5	462.3	582.3	428.7
40 cm	266.7	580.5	695.6	514.3
60 cm	260.0	593.6	669,1	507.6
Average	256.1	545.5	649.0	483.5
LSD 0.05	18.3	27.6	33.6	25.8
0.01	30.2	45.5	55.4	42.5

The highest average seed yield was achieved sowing at 40 cm spacing distance (514.3 kg ha⁻¹), followed by 60 cm (507.6 kg ha⁻¹), which was significantly higher compared to the yield achieved at 20 cm of row spacing (428.7 kg ha⁻¹). Going by the years, the differences in yields were the smallest, whereas in the second and third year, sowing at 40 and 60 cm row spacing resulted in significantly higher yields as compared to the yields from sowing at the row spacing of 20 cm. This indicates that row spacing has a significant influence on sainfoin seed yields. Similar results were found by Bratu *et al.* (1981), Manea (1985), Altın and Tuna (1996), Mohajer *et al.* (2011), Stevović *et al.* (2012) who also propose the optimal row spacing for sowing sainfoin to be ranging from 50-80 cm

Germination energy

Germination energy is an important biological trait of a seed, as well as a significant indicator of the quality and life ability of the seed. The average germination energy for the period of three years was 84.1%, with the highest (89.9%) being observed in 2013 and lowest (79.9%) in 2012 (table 3). Looking at the

influence of row spacing on germination energy, a correlation was observed: the greater the row spacing, the greater the germination energy, ranging from 81.4% (20 cm spacing) to 86.7% (60 cm spacing). Still, the differences in germination energy percentages between the examined spacings were not significant, which indicates a low variation coefficient (CV), which ranged from 2.66 % in 2013 to 3.99 in 2011 (table 3). Similar results were found by Stanisavljević *et al.* (2004) and Stevović *et al.* (2012), who confirmed the correlation between germination energy and row spacing.

Germination rate

The average sainfoin seed germination rate was 87.6%, highest in 2013 (90.6%) and lowest in 2012 (83.7%). In terms of row spacing, the highest percentage (90.4%) was obtained at the greatest row spacing (60 cm), and while the germination rate decreased along with the row spacing (see table 3), the differences were not significant (CV ranged 2.32 – 4.01 %). Mohajer *et al.* (2013) found somewhat lower average of seed germination for 10 populations of sainfoin (81.4%). Examining the effect that row

spacing has on the yield and seed quality of sainfoin, Stevovic *et al.* (2012) argue that the seed germination rate increased with the increase of row spacing ranging from 81.6% (at 20 cm of spacing) to 92.6% (at 80 cm of spacing), whereas the seed germination differences among sainfoin cultivars were not significant.

Hard kernels

The usual occurrence among perennial legumes seeds is the occurrence of hard kernels. Those kernels usually have good germination, but the impermeable seedling prevents water absorption necessary for the germination of the seed. The presence of greater quantities of such kernels is unfavorable, due to the consequences, such as uneven germination and rarefied crops. The average share of hard kernels was

3.7%, and ranged from 3.1 % in 2013 to 4.8 % in 2012 (table 3). Regarding the row spacing, the highest share of hard kernels (4.2%) was observed in sowing at the smallest row spacing (20cm), whereas 40 and 60 cm of row spacing yielded the same share of hard kernels (3.5%). The greatest variations in hard kernels shares occurred among different distances in row spacing, also indicated by the CV, which ranged from 8.53% in 2013 to 16.73% in 2012 (table 3). Higher hard kernel shares during 2012 could be explained by the unfavorable conditions, which caused low yields and smaller pods. Similar results were obtained by Stanisavljevic *et al.* (2004), who observed an average share of hard kernels at 3.5%, concluding that with the increase of crop density goes the increase of hard kernels share.

Table 3. Effect of row spacing on seed quality of sainfoin (2011-2013).

Year	Row Spacing	Germination energy (%)	Germination rate (%)	Hard kernels (%)	1000-kernel weight (g)
2011	20 cm	82.3	85.1	3.6	22.4
	40 cm	86.5	88.3	3.0	24.7
	60 cm	89.1	92.2	3.2	25.9
Average		85.9	88.5	3.3	24.3
CV (%)		3.99	4.01	9.34	7.32
2012	20 cm	77.8	81.6	5.8	18.6
	40 cm	79.3	83.4	4.6	22.2
	60 cm	82.5	86.2	4.3	23.8
Average		79.9	83.7	4.8	21.5
CV (%)		3.00	2.77	16.73	12.39
2013	20 cm	84.1	88.6	3.3	22.8
	40 cm	87.2	90.5	2.8	24.9
	60 cm	88.6	92.8	3.0	25.8
Average		86.6	90.6	3.1	24.5
CV (%)		2.66	2.32	8.53	5.43
Average 2011-2013	20 cm	81.4	85.1	4.2	21.3
	40 cm	84.3	87.4	3.5	23.9
	60 cm	86.7	90.4	3.5	25.2
Average		84.1	87.6	3.7	23.5
CV (%)		3.15	3.03	10.98	8.45

Another important indicator of seed quality is the 1000 kernel weight, because it indicates the size and fullness of the seed. The average 1000 kernel weight during the three years of research was measured at 23.5 g. The heaviest 1000 kernel weight (24.5 g) was obtained in 2013, the year considered as most suiting for seed production of sainfoin, whereas the lightest 1000 kernel weight (21.5 g) occurred in 2012 (table

3). In terms of row spacing, the heaviest 1000 kernel weight was obtained at 60 cm and was measured at 25.2 g, while the least was measured at 20 cm spaced rows and amounted to 21.3 g. The greatest variations of 1000 kernel weight depending on the row spacing occurred during 2012 (CV 12.39%), and the least (CV 7.32%) in the year of crop establishment, 2011. Hosaininejadmir *et al.* (2011) claim the average of

1000 kernel weight for 34 population to have been measured at 22.8 g and ranged from 19 – 28 g, which indicates a great influence the genetic potential has on 1000 kernel weight. Depending on the sowing method, the 1000 kernel weight average for 10 populations of sainfoin was recorded at two different amounts. On the one hand, while using the 50x50 cm spaced plants method for sowing individual plants, the average amounted to 21.9 g, and ranged from 19.4 to 23.6 g. On the other hand, sowing plants in sward condition 50 cm apart, the average weight was 21.1 g, and ranged from 18.9 to 23.4 g (Mohajer *et al.* 2011). Stevovic *et al.* (2012) found similar results, claiming that the 1000 kernel weight ranged from 20.1 g at 20 cm spaced rows to 24.8 g at 80 cm.

Conclusion

The highest yield was achieved during 2013 (649.0 kg ha⁻¹), with the lowest one in the year of the establishment of crops, 2011 (256.1 kg ha⁻¹).

The highest seed yield was achieved at 40 cm of distance in between the rows (514.3 kg ha⁻¹), followed by the yields at the distance of 60 cm (507.6 kg ha⁻¹), and finally the lowest yield at 20 cm of row spacing (428.7 kg ha⁻¹). Row spacing had a significant influence on germination energy which had been growing along with the increase of row spacing. It ranged from 81.4% at 20 cm to 86.7% at 60 cm of row spacing. The highest was achieved at 60 cm of row spacing (90.4%), and the lowest (85.1%) at 20 cm. At the spacing distance of 20 cm, the highest hard kernels share (4.2%) was observed, whereas their share at 40 and 60 cm of spacing was 3.5%. Row spacing affected the seed mass significantly, in such a manner that the highest mass was observed at the spacing of 60 cm (25.2 g), and lowest one at 20 cm (21.3 g).

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