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# INFLUENCE OF INTER-ROW SPACING AND CULTIVAR ON THE YIELD COMPONENTS OF SOYBEAN (*Glycine Max.* [L.] Merr.)

## SUMMARY

Influence of inter-row spacing on a productivity of soybean yield was studied on low carbonate chernozem soil in Serbia.

The number of pods per plant during two-year research for row spacing and cultivar was averagely 31.7. On average, the highest number of pods per plant in two-year research was at the smallest spacing (34.1) for the cultivars included in studies. Compared to standard planting (45 cm row spacing), it was higher by 6.2%, and by 15% as compared to the largest spacing (70 cm row spacing). Mean squares from the analysis of variance of pods per plant was statistically significant effect from row spacing, cultivars and their interaction in 2003 and was statistically significant effect from row spacing and cultivars in 2004.

The highest 1,000-grain weight (175.1 g) was achieved at the smallest inter-row spacing. It decreased at bigger row spacing for mostly 4.5%. The highest value of 1,000-grain weight (193.5 g) was present in cultivar Bosa, and the lowest (141.3 g) in cultivar Dragana.

Similar to grain weight per plant, the largest weight of 1,000 grains, on average for the cultivars included in the research, was achieved by sowing at 20 cm row spacing and was 175.1 g. With increase of row spacing, 1,000-grain weight decreased by 2.8 g to 7.9 g. A similar decreasing trend can be observed at the varieties respectively.

**Key words:** inter-row spacing, yield components, soybean, cultivar

## INTRODUCTION

The great importance of soybean (*Glycine Max.* [L.] Merr.) is in its chemical composition of the grain, which contains about 40% of protein and 20% of oil. Due to possibility of using whole grain, as well as its protein and oil in particular, soybean is widely used not only in food, but also in other industries, as well as in international trade [1, 2 and 3].

The proper arrangement of plants in appropriate plant density is one of the requirements to achieve high and stable yields during intensive production of soybean. It is well known that the ideal vegetation space is a square shape.

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However, in practice it is difficult to achieve a square shape if soybean is sown at inter row-spacing of 50 cm and intra row-spacing of 3-5 cm. Changing the shape of growing space and row spacing leads to change in microclimate growing conditions (light, relative humidity, aeration), where soybean is very sensitive, especially in the flowering stage. Therefore, a form of vegetative area or sowing modes was study object in almost all areas of growing soybeans. When sowing with greater spacing is performed, large portion of the sunlight falls between the rows and remains unused, especially in the initial part of soybean growing season [4 and 5].

The aim of this study was to examine the effect of inter row spacing at the same density on the yield components of soybean. This would give quite a contribution to a better understanding of the impact of row spacing, and in this regard, specific recommendations related to modern production technology of soybean.

## MATERIALS AND METHOD

Research of the effect of inter-row spacing and cultivar on the yield components of soybean was conducted at the experimental field of Maize Research Institute in Zemun Polje, Serbia on low carbonate chernozem soil in 2003 and 2004. Field micro-experiments were carried out as a two-factorial, using split-plot method in four replications.

This research covered two factors: 1. Inter-row spacing (A): 20 cm distance between rows, 45 cm distance between rows, 70 cm distance between rows and 2. Cultivar (B): Bosa (0 maturity group), Maize Research Institute, Zemun Polje, Balkan (I maturity group), Institute of Field and Vegetable Crops, Novi Sad; Dragana (II maturity group), Selsem.

Crop density within cultivars was the same for all variants, which was 500,000 plants per hectare for cultivar Bosa, 450,000 plants per hectare for cultivar Balkan, and 400,000 plants per hectare for cultivar Dragana. Different densities were taken for each cultivar because of previous research that found that they exert maximum genetic potential in these conditions. The size of experimental plots was 5.4 m (6.0 x 0.9 m) for a combination of sowing at 45 cm between rows, 6.0 m (6.0 x 1.0 m) for a combination of sowing at 20 cm between rows and 8.4 m (6.0 x 1.4 m) for sowing at 70 cm spacing between rows.

Standard agricultural practices for soybean production were applied in the experiments, with the exception of the studied factors. In both research years, preceding crop to soybean was corn. Deep plowing was performed to a depth of 25 cm in fall, immediately after maize harvest and on this occasion 100 kg ha$^{-1}$ of UREA (46% N) was applied. Seedbed soil preparation was performed in spring. Sowing was performed on April 23 in the first year of study and May 5 in the second year of study. Just before sowing, seeds were inoculated by microbiological chemical preparation, NS-Nitragin. Hand weeding and hoeing was performed two times during the growing season. Harvesting was performed by hand on September 10 and September 17, in the first and second year of the study. After harvest, samples from each plot and all replications consisting of ten plants were taken for laboratory analysis of following important characteristics of fertility: the number of pods per plant and 1,000-grain weight.

The obtained experimental data were analyzed by analytical and descriptive statistics using the statistical package STATISTICA for Windows 10. Significance of differences between the calculated mean values of the studied characteristics (year and genotype) was tested by the two-way analysis of variance. All significant values obtained in the LSD test were calculated for significance levels of 0.05% and 0.01.

**Meteorological conditions.** An analysis of thermal conditions concluded that the temperature in 2003 was higher 1.9°C compared to 2004 and long-term average. In 2004, the temperature was close to multi-year average (Tab. 1).

Table 1. Air temperature (°C) and sum of rainfall (mm), 2003-2004, Zemun Polje, Serbia

| Month | Temperature | | Rainfall | | Temperature | Rainfall |
|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2003 | 2004 | Average | |
| 4. | 11.5 | 12.9 | 14.6 | 27.2 | 11.5 | 49.1 |
| 5. | 20.9 | 16.6 | 36.4 | 53.6 | 17.1 | 62.4 |
| 6. | 24.6 | 20.4 | 19.0 | 125 | 19.9 | 79.9 |
| 7. | 22.6 | 22.9 | 105.4 | 66.4 | 21.8 | 61.5 |
| 8. | 24.7 | 21.7 | 26.4 | 39.4 | 21.6 | 51.5 |
| 9. | 19.2 | 16.2 | 41.2 | 35.8 | 17.2 | 44.7 |
| Total/Average | 20.6 | 18.5 | 243.0 | 347.4 | 18.2 | 349.1 |

It should be noted that an average monthly temperature in May and June 2003 was higher compared to 2004 and multi-year average for about 4°C and 4.5°C. Very high average monthly temperature in August 2003, which was a 3°C higher than in 2004 and multi-year average. That significantly influenced on the yield, since the soybean crop was in the stage of grain filling. In September 2003, high temperature in the first ten-day period accelerated seed ripening and soybean harvest (Tab. 1).

Amount and distribution of rainfall per year varied so that water regime in a year with less rainfall (2003) significantly affected the production of soybean (Tab. 1). In 2004, rainfall during growing season was at multi-year average and higher by about 105 mm, compared to 2003. In the first year, when weather was unfavorable for growing soybean, there was less rainfall in April, May and especially in June (only 19 mm). In relation to a long-term average, rainfall deficit, combined with high temperatures especially in May and June, has caused a drastic reduction in grain yield of soybean. Higher amount of rainfall was recorded in July (105.4 mm). Far better distribution and quantity of rainfall were recorded in 2004, a year with more favorable weather. Higher amount of precipitation, as well as its favorable distribution especially in the critical stages of water, combined with favorable temperatures, had favorable impact on the growth and development of soybean. It has certainly influenced better yield and quality of soybean genotypes. Our study is consistent with Popovic *et al.* (2013)

research, where authors stated that there was a significant effect of temperature and rainfall on soybean yield.

**Soil conditions.** Parental material, calcareous forest (soil organic matter) is very well connected with the mineral part, so it is a well-formed organic-mineral complex.

Table 2. Chemical characteristics of soil on the experimental field, Zemun Polje, Serbia

| Soil depth | pH | | $CaCO_3$ | Humus | Total N | C/N | Available N (ppm) | | | mg/100g soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | KCl | (%) | (%) | (%) | | $NH_4$ | $NO_3$ | $NH_4$+$NO_3$ | $P_2O_5$ | $K_2O$ |
| 0-20 cm | 7.95 | 7.25 | 1.6 | 2.87 | 0.180 | 9.2:1 | 8.4 | 15.4 | 23.8 | 26.8 | 25.4 |
| 20-40 cm | 8.00 | 7.40 | 2.2 | 2.72 | 0.175 | 9.0:1 | 4.9 | 16.8 | 21.7 | 26.8 | 24.3 |

Table 2 shows that soil was well supplied with total nitrogen. According to the pH factor, it is evident that this is a soil of neutral to slightly alkaline reaction. $CaCO_3$ content at a depth of 20 cm was 1.6%, while at a depth of 40 cm was 2.2% and indicates that the soil was slightly calcareous. The humus content is variable and gradually decreases with depth. Its percentage at a depth of 20 cm is 2.87%, and at depths of 20 to 40 cm was 2.72%, which indicates high coverage with soil humus and substantial share of nitrogen therein. In addition, soil supply with phosphorus and potassium is higher. Chernozem, with its favorable chemical and physical properties, is an ideal pursued by every user of the land because it provides high yields of major agricultural land.

## RESULTS AND DISCUSSION

### Influence of row spacing and cultivar on number of pods per plant

The number of pods per plant during two-year research for row spacing and cultivar was averagely 31.7. On average, the highest number of pods per plant in two-year research was at the smallest spacing (34.1) for the cultivars included in studies. Compared to standard planting (45 cm row spacing), it was higher by 6.2%, and by 15% as compared to the largest spacing (70 cm row spacing). Mean squares from the analysis of variance of pods per plant was statistically significant effect from row spacing, cultivars and their interaction in 2003 and was statistically significant effect from row spacing and cultivars in 2004 (Tab. 3, 3.1).

The highest number of pods per plant (45.2) was achieved by cultivar Balkan in 2004 at smallest spacing, and the lowest (17.7) by cultivar Bosa in 2003, when there was 70 cm distance between rows (Tab. 3).

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On average, the highest number of pods per plant for row spacing in two-year research was recorded with cultivar Dragana (34.7) and was higher by 4.4% compared to Balkan cultivar, and 28% compared to cultivar Bosa. In all three cultivars, respectively, the greatest number of pods per plant was recorded at smallest spacing (20 cm between rows) and almost uniformly decreased with increase of spacing (Tab. 3).

Tab.3. Number of pods per plant of estimated soybean cultivars in different row spacing

| Year | Row spacing (A) | Cultivar (B) | | | Average | Index (%) |
|---|---|---|---|---|---|---|
| | | Bosa | Balkan | Dragana | | |
| 2003 | 20 | 20.1 | 25.9 | 30.7 | 25.6 | 100.0 |
| | 45 | 19.2 | 25.6 | 28.7 | 24.5 | 95.7 |
| | 70 | 17.7 | 21.2 | 27.8 | 22.2 | 86.7 |
| | Average | 19.0 | 24.2 | 29.1 | 24.1 | 100.0 |
| | Index (%) | 100.0 | 127.4 | 153.2 | - | - |
| 2004 | 20 | 38.5 | 45.2 | 44.2 | 42.6 | 100.0 |
| | 45 | 35.9 | 43.0 | 39.7 | 39.5 | 92.7 |
| | 70 | 31.0 | 39.8 | 36.7 | 35.8 | 84.0 |
| | Average | 35.1 | 42.7 | 40.2 | 39.3 | 163.1 |
| | Index (%) | 100.0 | 121.7 | 114.5 | - | - |
| Average | 20 | 29.3 | 35.6 | 37.5 | 34.1 | 100.0 |
| | 45 | 27.6 | 34.3 | 34.2 | 32.0 | 93.8 |
| | 70 | 24.4 | 30.5 | 32.3 | 29.0 | 85.0 |
| Total average | | 27.1 | 33.5 | 34.7 | 31.7 | - |
| Index (%) | | 100.0 | 123.6 | 128.0 | - | - |

| LSD | year 2003 | | | | year 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | BxA | AxB | A | B | BxA | AxB |
| 0.05 | 0.67 | 0.45 | 0.79 | 0.93 | 1.26 | 1.07 | 1.86 | 1.97 |
| 0.01 | 1.02 | 0.62 | 1.08 | 1.34 | 1.92 | 1.47 | 2.54 | 2.80 |

Table 3.1. Mean squares from the analysis of variance of pods per plant, 2003 – 2004

| Sourse of variation | 2003 Df | 2003 MS | 2004 Df | 2004 MS |
|---|---|---|---|---|
| Replications | 3 | 1.8459** | 3 | 1.3749 |
| Row spacing A | 2 | 34.7103** | 2 | 137.0918** |
| Cultivar B | 2 | 303.6295** | 2 | 179.2090** |
| A*B | 4 | 3.7520** | 4 | 2.7295 |
| Error | 24 | 0.3242 | 24 | 1.5708 |

In 2003, which was less favorable for soybean cultivation, the number of pods was 24.1, averagely for the factors included in studies. The highest number of pods per plant was recorded at the smallest spacing (20 cm between rows). It was 25.6 and decreased with increase of row spacing from 4.3 to 13.3%. The differences are very significant. In this research year, the highest number of pods was found in late cultivar Dragana (29.1). The number of pods of this cultivar is very significantly higher than the cultivars Bosa and Balkan. In addition, there is an interaction AxB, which is statistically significant. Interaction BxA is not present at Balkan cultivar between smallest (20 cm) and standard sowing (45 cm), whereas Bosa cultivar between these two variants of sowing is registered at the significance level of 95% (Tab. 3).

The changes in the number of pods with increase of row spacing were more distinct in 2004, as it was a year with more favorable temperature regime and rainfall during the growing season of cultivars included in the research. The number of pods per plant, averagely, amounted to 39.3 and was as much as 63.1% higher than during the unfavorable 2003. However, similar to 2003, the highest number of pods was found in the variant of smallest sowing (20 cm) and was 42.6. Increase of row spacing decreased number of pods by 3.1 and 6.8 pods, and the differences were evaluated as statistically significant.

In the second year of research (2004), in contrast to the first year, the highest number of pods per plant was recorded with Balkan cultivar (42.7) and was statistically significantly higher than the number of pods per plant at genotypes Bosa and Dragana. Statistically significant difference in the number of pods per plant during AxB interaction was found in every researched spacing, but only between cultivars Bosa and Balkan. The interaction of cultivar x row spacing (BxA) is statistically justified in all three cultivars between variants of square (20 cm) and standard sowing (45 cm between rows), while other interactions of this type were found at a significance level of 99% (Tab. 3).

Similar trends in change of number of pods with increase of row spacing have been noticed by [6 and 5] while [7] suggested that greater spacing (45 and 60 cm) makes strong branching plants, which in turn contributes to greater number of pods per plant.

**Influence of row spacing and cultivar on 1,000-grain weight**

1,000-grain weight is a major yield component (Popovic *et al*. 2012). 1,000-grain weight in two-year research amounted to 171.5 g and varied in a range of 124.0 g in late cultivar Dragana on variation of largest sowing (70 cm between rows) to 200.6 g in early-maturing cultivar Bosa on variant of smallest sowing (20 cm between rows), Tab. 5.

Similar to grain weight per plant, the largest weight of 1,000 grains, on average for the cultivars included in the research, was achieved by sowing at 20 cm row spacing and was 175.1 g. With increase of row spacing, 1,000-grain weight decreased by 2.8 g to 7.9 g. A similar decreasing trend can be observed at the varieties respectively (Tab. 5, 5.1).

In this two-year study, on the average for the studied spacing, the highest 1,000-grain weight was observed in cultivar Bosa (193.5 g). Genotypes with longer vegetation period, Balkan (maturity group I) and Dragana (maturity group II), gave a lower 1,000-grain weight compared to early-maturing cultivar Bosa (maturity group 0) by 7.1% and even 27% (Tab. 5).

In 2003, which was meteorologically unfavorable, 1,000-grain weight was 163.9 g, on the average for the factors involved in the research. With increase of row spacing to 45 cm and 70 cm, it was uniformly reduced by 2.6 to 5.6%. Mean squares from the analysis of variance of 1,000-grain weight was statistically significant effect from row spacing, cultivars and their interaction in 2003 and was statistically significant effect from row spacing and cultivars in 2004 (Tab. 5, 5.1).

Table 5. Soybean 1,000-grain weight (g) of estimated cultivars in different row spacing

| Year | Row spacing (A) | Cultivar (B) | | | Average | Index (%) |
|---|---|---|---|---|---|---|
| | | Bosa | Balkan | Dragana | | |
| 2003 | 20 | 197.0 | 178.8 | 129.8 | 168.5 | 100.0 |
| | 45 | 191.1 | 175.5 | 125.9 | 164.2 | 97.4 |
| | 70 | 181.6 | 171.3 | 124.0 | 159.0 | 94.4 |
| | Average | 189.9 | 175.2 | 126.6 | 163.9 | 100.0 |
| | Index | 100.0 | 92.3 | 66.7 | - | - |
| 2004 | 20 | 200.6 | 187.1 | 157.0 | 181.6 | 100.0 |
| | 45 | 197.2 | 186.9 | 156.9 | 180.3 | 99.3 |
| | 70 | 193.3 | 178.4 | 154.4 | 175.4 | 96.6 |
| | Average | 197.0 | 184.1 | 156.1 | 179.1 | 109.6 |
| | Index | 100.0 | 93.5 | 79.2 | - | - |
| Average | 20 | 198.8 | 183.0 | 143.4 | 175.1 | 100.0 |
| | 45 | 194.2 | 181.2 | 141.4 | 172.3 | 98.4 |
| | 70 | 187.5 | 174.9 | 139.2 | 167.2 | 95.5 |
| Total average | | 193.5 | 179.7 | 141.3 | 171.5 | - |
| Index (%) | | 100.0 | 92.9 | 73.0 | - | - |

| LSD | year 2003 | | | | year 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | BxA | AxB | A | B | BxA | AxB |
| 0.05 | 1.25 | 1.61 | 2.80 | 2.60 | 4.73 | 2.21 | 3.84 | 5.66 |
| 0.01 | 1.89 | 2.21 | 3.83 | 3.63 | 7.16 | 3.03 | 5.25 | 8.29 |

Table 5.1. Mean squares from the analysis of variance of 1,000-grain weight, 2003-2004

| Sourse of variation | 2003 Df | 2003 MS | 2004 Df | 2004 MS |
|---|---|---|---|---|
| Replications | 3 | 0.3079 | 3 | 6.9769 |
| Row spacing A | 2 | 270.6979** | 2 | 128.3125** |
| Cultivar B | 2 | 13202.3643** | 2 | 5251.8540** |
| A*B | 4 | 26.8439** | 4 | 16.1042 |
| Error | 24 | 3.0448 | 24 | 10.5966 |

There are statistically significant differences in 1,000-grain weight between different row spacing. By analyzing the cultivars, it can be concluded that the highest 1,000-grain weight was observed in the early-maturing cultivar Bosa (189.9 g). It was higher than 1,000-grain weight at genotypes Balkan and Dragana by 7.7 to 33.3%, and these differences are evaluated as statistically significant. In addition, it should be noted that the interaction row spacing x cultivar (AxB) is statistically significant in all variants of distance between the rows and in all genotypes. There was no statistically significant difference in 1,000-grain weight between sowing at 45 and 70 cm row spacing at Dragana cultivar, but at cultivar Balkan this difference is present at the level of significance of 95% between sowing at 20 and 45cm. Other types of interactions BxA are statistically significant (Tab. 5, 5.1).

Slightly less variation in 1,000-grain weight was recorded in meteorologically favorable 2004. The reduction in the value of 1,000-grain weight, with increase of row spacing, ranged from only 1.3 g (variant of sowing at 45 cm row spacing) to 6.2 g (variant of sowing at 70 cm row spacing). Statistically significant differences in 1,000-grain weight are not present only between the smallest (20 cm) and the standard sowing (45 cm). In 2004, the largest 1,000–grain weight, averagely for factors included in research, was observed in cultivar Bosa. It amounted to 197.0 g and was statistically higher than in varieties Balkan and Dragana. The difference compared to Balkan genotype was 6.5%, and compared to Dragana genotype 20.8% (Tab. 5, 5.1).

Similar to year 2003, statically very significant difference in 1,000-grain weight was observed among all cultivars included in research. The interaction of cultivar x row spacing is present at cultivar Bosa between square (20 cm) and rectangular planting (70 cm between rows), as well as in cultivar Balkan between sowing at 20 cm and 70 cm and 45 cm and 70 cm between rows at very high significance level (99%). The high significance of BxA interaction between variants of sowing at 45 cm and 70 cm between rows was observed in cultivar Bosa (Tab. 5).

Analysis of the data for 1,000-grain weight showed that this very important yield component at least depended on row spacing and year, which is not the case with previously analyzed parameters. It was higher by 9.6% in 2004 compared to less favorable year 2003. It was higher for about 5% in both research years by increase of row spacing. It is important to note that this feature is still more a characteristic itself for each cultivar i.e. genotype characteristic. Lower values of 1,000-grain weight in cultivar Balkan, which is characterized by large seed, and cultivar Dragana ensued due to adverse environmental conditions during flowering and pod formation in 2003 and during grain filling in 2004 (Tab. 5). Our results are in agreement with those of [8 and 9].

## CONCLUSION

Based on our two-year research of influence of row spacing and yield components of soybean, following conclusions may be suggested:

- Planting at different spacing, as well as selected soybean cultivars, had a significant impact on productivity parameters of soybean.
- The number of pods per plant during two-year research for row spacing and cultivar was averagely 31.7. On average, the highest number of pods per plant in two-year research was at the smallest spacing (34.1) for the cultivars included in studies. Compared to standard planting (45 cm row spacing), it was higher by 6.2%, and by 15% as compared to the largest spacing (70 cm row spacing).

- The highest 1,000-grain weight (175.1 g) was achieved at the smallest inter-row spacing. It decreased at bigger row spacing for mostly 4.5%. The highest value of 1,000-grain weight (193.5 g) was present in cultivar Bosa, and the lowest (141.3 g) in cultivar Dragana.
- It can be concluded from our study that in terms of arid and semiarid climate, which encompasses the majority of the country, significantly higher productivity can be achieved with a smaller spacing, which in our studies is 20 cm.

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**UTICAJ MEĐUREDNOG RASTOJANJA I SORTE NA KOMPONENTE PRINOSA SOJE (*Glycine Max.* [L.] Merr.)**

**Rezime**

Istraživanja uticaja međurednog rastojanja i sorte na produktivnost soje obavljena su na slabo karbonatnom černozemu, u Srbiji.

Broj mahuna po biljci je, u dvogodišnjem istraživanju, u proseku za međuredna rastojanja i sorte, iznosio 31,7. U proseku za sorte obuhvaćene istraživanjima, najveći broj mahuna po biljci, u dvogodišnjem periodu, ostvaren je pri uskorednoj setvi tj. pri najmanjem međurednom rastojanju i iznosio je 34,1. U odnosu na standardnu setvu (45cm između redova), bio je veći za 6,2%, a u odnosu na širokorednu (70cm između redova) 15%.

Najveća masa 1.000 zrna ostvarena je setvom na najmanje međuredno rastojanje (175,1 g). Sa povećanjem rastojanja između redova smanjivala se za najviše 4,5%. Najveća masa 1.000 zrna zabeležena je kod sorte Bosa (193,5 g), a najmanja kod sorte Dragana (141,3 g).

Slično masi zrna po biljci, najveća masa 1.000 zrna, u proseku za sorte obuhvaćene istraživanjima, ostvarena je pri setvi na 20 cm međurednog rastojanja i iznosila je 175,1 g. Sa povećanjem međurednog rastojanja, masa 1.000 zrna se smanjivala za 2,8 g odnosno 7,9 g. Sličan trend smanjenja može da se uoči i po sortama pojedinačno.

**Ključne reči:** međuredno rastojanje, osobine rodnosti, soja