Bulgarian Journal of Agricultural Science, 26 (No 3) 2020, 533–539

Analysis of soybean growth in regard to different row-spacing

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Abstract

Ulafić, A., Varga, I., Stošić, M., Iljkić, D. & Antunović, M. (2020). Analysis of soybean growth in regard to different row-spacing. *Bulg. J. Agric. Sci., 26 (3)*, 533–539

The aim of this study was to analyze soybean plant development during 2018 vegetation and finally seed yield regard to different row-spacing:12.5, 25, 50 and 70 cm. Soybean genotype Ika (0 – 1 maturity group) was sown on 26 April 2018. At the beginning of each month (June-September), therefore the plant sampling was done at V_3, R_3, R_6 and R_7 growth phase. In each sampling date 20 plants from every row-spacing were taken in order to determine plant height (cm plant^{-1}), fresh plant mass (g plant^{-1}) and dry matter weight (g plant^{-1}). Final harvest was done on 11th October 2018. Regression analysis showed that in September (R_7 growth phase) increasing the stem height by 1 cm, the fresh mass of the plant increased by 1.76 g to the plant^{-1} and the dry matter by 0.22 g plant^{-1} Different row-spacing had very significant influence ($p < 0.01$) on stem elongation through the vegetation period. The largest increase in stem, fresh matter and dry matter of soybean plants was determined from 1st July to 1st August, when the average stem increment was 48.8 cm per plant, or 1.6 cm plant^{-1} day^{-1}. On average, the highest fresh and dry mattter acuumulation was determined in the period from 1st July to 1st August (R_3 to R_6) and it account total 90.73 g plant^{-1} and 26.60 g plant^{-1}, respectively. In R_7 growth phase at the beginning of September, the highest soybean stem was at 50 cm row-spacing, when it was on average 119.7 cm in plant^{-1}, or 13.9% more than the average of the experiment (103.1 cm). The highest positive and significant correlation was found at 1st July between soybean fresh mater and dry matter ($r = 0.964$***) and on the opposite the highest and very significant negative corelation was determined at 1st June between plant height and seed yield per plant ($r = -0.712$***). There were vary significant inflence ($p < 0.05$) of row-spacing on seed yield. The highest soybean yield per plant was found in row-spacing 70 cm (19.79 g plant^{-1}) and the lowest in row-spacing of 12.5 cm (8.65 g plant^{-1}). Generally, the highest seed yield was determined at 25 cm row-spacing where it was on average 1.90 t ha^{-1}.

Keywords: soybean; row-spacing; fresh matter; dry matter; yield

Introduction

In historical pathway of soybean cultivation, the first record of soybeans in Yugoslavia was in 1804, when it was used as a supplement in animal feed (Hartman et al., 2011). Nowadays, according to FAO Stat (2019) in 2017 world's soybean harvested area was 123 551 146 ha and the highest share of soybean production is located in the "Big-3" (USA, Brazil and Argentina), which acounts 89% of world's total production in 2017. Unfortunally, soybean production is one of the biggest drivers of deforestation in South America. It causes widespread environmental damage, increases the use of pesticides.

Soybean oil is considered healthier than most other vegetable oils, due to the presence of a good variety of essential fatty acids in it, which the body needs in order to remain healthy. The very impotant by product of soybean oil extraction in soybean meal. Soybean meal is the most commonly used and the most important protein source used to feed farm animals but also dominant protein source for human nutrition (Pantalone, 2012; Novoselec et al., 2018). In 20-year period (1999-2018) in EU-27 the total supply with soybean oil was on average 3 317 000 t, soybean meal 32 384 850 t (Index Mundi, 2018). Soybean seed production in the EU-27 in the period from 1999 to 2018 was on average 1 461 100 t.

Soybean row-spacing is one management practice most often considered by growers as potentially important to increase yield (Rezi et al., 2019). In common practice, in Republic of Croatia the seed rate in sowing is around 100 to 130 kg ha^{-1}. Even thought there are several abiotic conditions (Mari et al., 2015; Markulj Kulundzic et al., 2016), which have a great influence on the plant establishment, growth and final yield, proper agrotechnical measures can minimize negative external influence (Varga et al., 2015; Jelić et al., 2018; Cociu et al., 2019; Jukić et al., 2019).

The monitoring of crop growth and performance during vegetation is an important aspect of agricultural management. Competition among plants for sunlight, nutrient, water or space is one of the most important factors that influence on the plant development and final yield. Light is the energy source of plants photosynthesis and light intensity has important influence on plant morphology, physiology and reproduction (Bing et al., 2015).

Except the final seeed yield, there are several yield components, which have great influence on the final yield. For example, Naydenova and Georgieva (2019) studied 28 cultivars of soybean of different maturity groups and according to the ANOVA analysis found more pronounced genotypic heterogeneity for soybean yield components as plant height, number of fertile nodes and branches and absolute mass of seeds.

This study aimed to analyze the changes in soybean growth (plant height, fresh and dry matter), plant development during vegetation and its correlation with seed yield per plant and total seed yield (t ha^{-1}) in different row-spacings (12.5, 25, 50 and 70 cm) in 2018.

Materials and Methods

Field trail

The field experiment was set up in Eastern part of Republic of Croatia (location Biškupci). Previous crop was maize. At 26th April 2018 the soybean cultivar Ika (Agricultural Institute Osijek) was sown. This cultivar is 0 – 1 maturity group. The protection of soybeans against weeds was done after the emergence of soybeans. There were no pest attack requiring the use of insecticides. After emergence (21st May 2018) the number of plants per m^2 was encounted in 4 replications. Therefore it was for row spacing 12.5, 25, 50 and 70 cm, it was on average 80, 73, 41 and 16 plants m^2, respectively.

Weather conditions

In soybean vegetation the mean air-temperature from March to October were 16.1°C which was for 2.6°C highet than the LTM (Table 1). At the begining of the vegetation, in April and May, the mean air-temperatures were higher than the LTM (5.0 and 3.4°C, respectively). In such conditions emergence was satisfied. Even though extreme events occurring during the summer period can have the most dramatic impact on plant productivity, the temperatures was a bit higher as compared to the LTM.

During soybean growth in 2018 the total rainfall (Table 2) was for 57.1 mm less than the LTM (488.2 mm). In the summer months (June, July and August) the monthly rainfall was higher than the LTM, so there was no lack of the rainfall in the soybean intensive growth.

Collection of the plant material

In soybean vegetation there were 4 sampling dates to analyze the stem height (cm $plant^{-1}$), fresh and dry matter (g $plant^{-1}$) of soybean plants. Plants were manually collected at the beginning of June to beginning of September. It corresponds to the growth stage: V_3 (1st June), R_3 (1st July), R_6

Table 1. The mean air temperature (°C) in 2018 soybean vegetation as compared to the long term mean (LTM = 1961-1990) for Meteorological station Slavonski Brod (Croatian Meteorological and Hydrological Service, 2018)

Month	Mean air temperature (°C) by decade			Average	LTM
	I	II	III		(1961 – 1990)
April	13.0	16.3	18.5	15.9	10.9
May	18.3	17.6	21.6	19.3	15.9
June	22.6	21.3	18.4	20.8	19.0
July	21.1	21.6	22.8	21.9	20.7
August	24.7	23.5	20.7	22.9	19.8
September	19.6	19.1	11.5	16.8	16.1
October	13.8	13.2	13.8	13.6	10.6
Average	19.0	18.9	18.2	18.7	16.1

Table 2. The total rainfall (mm) in 2018 soybean vegetation as compared to the long term mean (LTM = 1961–1990) for Meteorological station Slavonski Brod (Croatian Meteorological and Hydrological Service, 2018)

Month	Monthly rainfall, mm			Total	LTM
	I	II	III		(1961 – 1990)
April	10.8	6.6	0.3	17.7	57.7
May	81.9	15.3	7.6	104.8	73.0
June	40.8	42.5	36.5	119.8	86.3
July	17.2	12.3	93.4	122.9	82.7
August	13.2	0.8	11.8	25.8	73.4
September	19.2	1.0	9.3	29.5	61.6
October	2.7	0.3	7.6	10.6	53.5
Total	185.8	78.8	166.5	431.1	488.2

(1st August) and R_7 (1st September). At each sampling date 20 plants from every row-spacing were manually collected, marked and weighted. The plant samples were oven-dried at 105°C to determine dry matter. Therefore total of 320 individual plants were analyzed during growth. The final harvest was done on 11th October 2018. Grain moisture was 15%, with 2% impurities, and seed yield per unit area was converted to standard moisture of 13% and 2% impurities.

Statistics

The one-way ANOVA analysis was done in SAS 9.4. Linear regressions ($y = a + bx$) were calculated for plant height, fresh and dry matter accumulation during the growing season. The Pearson's correlation coefficient was also calculated in SAS 9.4 for determinate the relationship of plant growth parameters at each sampling date (plant height, fresh and dry matter accumulation) and final seed yield. The levels of significance were indicated with $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***) or *ns* for not significant.

Results

According to the regression analysis, in September (R_7 growth phase) in average for all row-spacing, it was found that by increasing the height of the soybean stem by 1 cm, the fresh mass of the plant increased by 1.76 g to the plant^{-1} and the dry matter by 0.22 g plant^{-1} (Figure 1). Different row-spacing had very significant influence ($p < 0.01$) on stem elongation through the vegetation period (Figure 2). The highest stem elongatgion was found between growth phase R_3 to R_6, which refers to period from 1st July to 1st August (Figure 2), when it was on average 48.8 cm plant^{-1} (1.58 cm plant^{-1} daily). In growth phase R_7 (1st September) the stem height varied from 95.2 cm (70 cm row-spacing) to 119.7 cm (50 cm row-spacing).

Different row-spacing had very significant influence ($p < 0.01$) on soybean fresh matter at 1st June and 1st September (Figure 3). At the beginning of the September the differences among fresh matter varied the most regard to row spacing. Thus, the fresh matter of the plant for all row-spacings averaged 159.25 g plant^{-1} at the beginning of September and it was the smalest at 12.5 cm row-spacing (108.10 g plant^{-1}) and the highest at 50 cm row-spacing (204.3 g plant^{-1}).

Dry matter accumulation had also linear trend during soybean growth (Figure 4). According to ANOVA, different row-spacing had significant ($p < 0.05$) influence on dry matter accumulation only at 1st June (V_3 growth phase) and very significant influence ($p < 0.01$) at 1st July (R_3 growth phase). In September (R_7 growth phase) average dry matter of the plants averaged 53.98 g plant^{-1} and the highest dry matter per plant was at 25 cm row spacing, which averaged 62.07 g of plant^{-1}.

The highest accumulation of fresh matter and dry matter was in the period from 1st July to 1st August (Figures 3 and 4), when it was increased on average for 90.73 g plant^{-1} and 26.60 g plant^{-1} (2.93 and 0.86 g plant^{-1} day^{-1}, respectively).

Generally, the correlations between fresh and dry matter accumulation were significant in every sampling date (Table 4), whereas the highest positive and significant correlation was found at 1st July between soybean fresh mater and dry matter (r = 0.964***). The highest and very significant ($p < 0.001$) negative corelation was determined at 1st June between plant height and seed yield per plant (r = – 0.712***). At the end of vegetation, in September there were negative correlations found between soybean fresh and dry matter and seed yield per unit area.

Different row-spacing had a significant influence ($p < 0.05$) on seed yield per plant (g plant^{-1}) and soybean seed yield per unit area (Table 3). The highest soybean seed yield per plant was at 70 cm row-spacing (19.79 g plant^{-1}) with row spacing and 12.5 cm (8.65 g plant^{-1}) row-spacing (Table 3). The highest soybean yield per plant was found in row spacing plants of 70 cm (19.79 g plant^{-1}) and the lowest

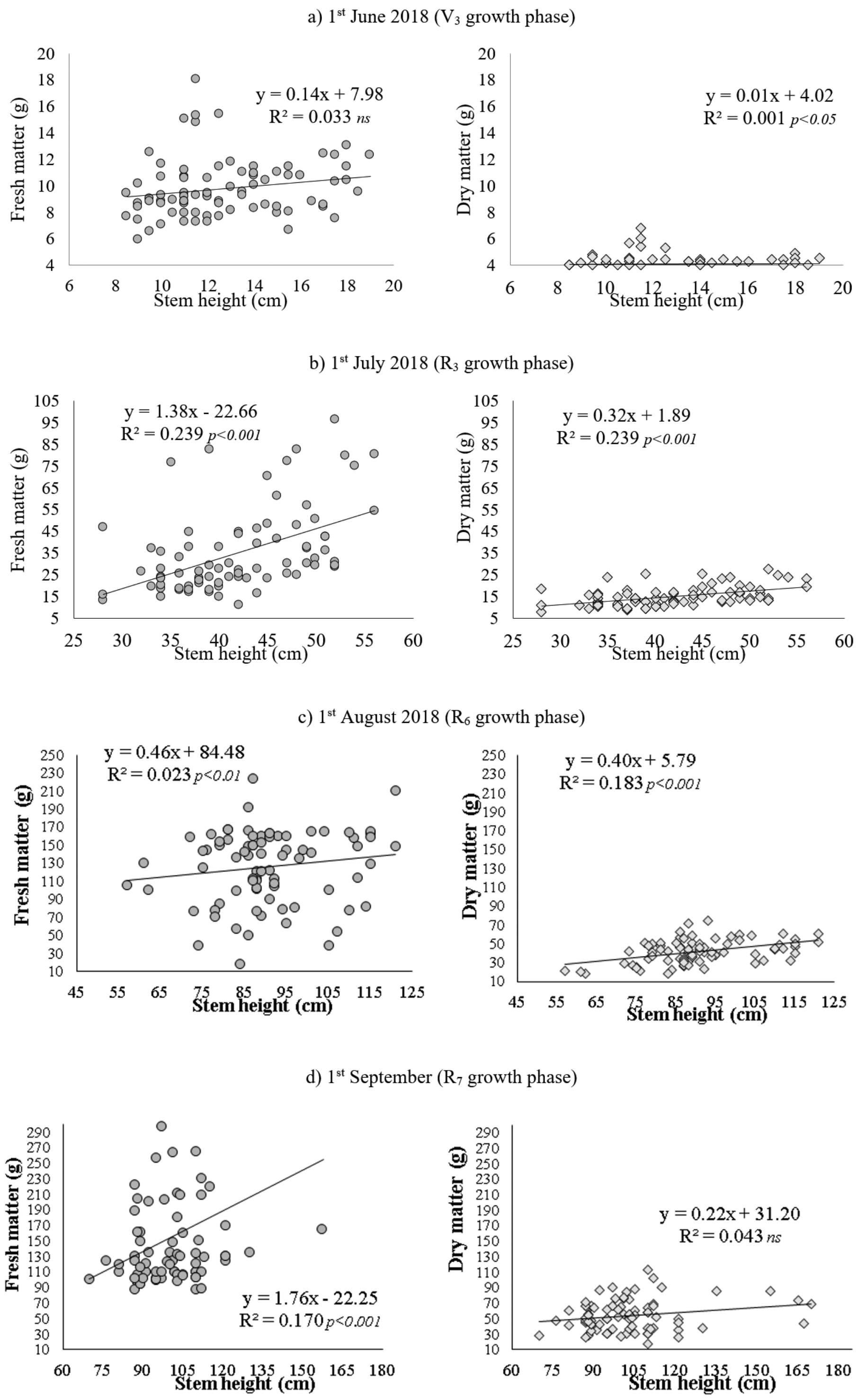

Fig. 1. Relationship between soybean fresh (on the left) and dry mass (on the right) increment and stem height from June to September 2018 (N = 80)

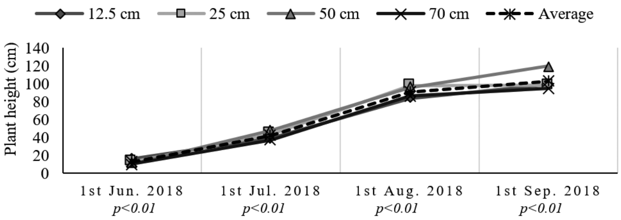

Fig. 2. Soybean stem height (cm plant^{-1}) in 2018 in relation to different row-spacing (the levels of significance were indicated with $p < 0.05$ (*), $p < 0.01$ (**) or *ns* for not significant)

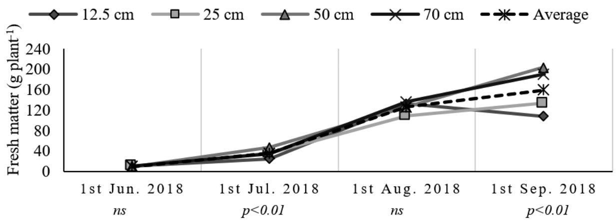

Fig. 3. Soybean fresh matter (g plant^{-1}) in 2018 in relation to different row-spacing (the levels of significance were indicated with $p < 0.05$ (*), $p < 0.01$ (**) or *ns* for not significant)

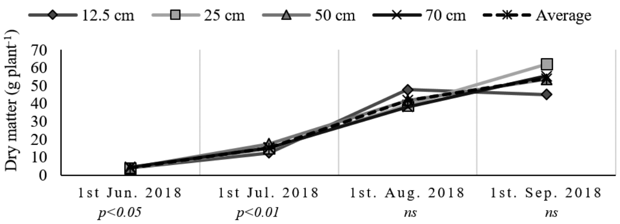

Fig. 4. Soybean dry matter (g plant^{-1}) in 2018 in relation to different row-spacing (the levels of significance were indicated with $p < 0.05$ (*), $p < 0.01$ (**) or *ns* for not significant)

in row-spacing of 12.5 cm (8.65 g plant^{-1}). Finally, the highest seed yield was determined at 25 cm row-spacing (Table 3), where it was on average 1.90 t ha^{-1}.

Discussion

Temperature is the main climatic factor determining where soybeans can be grown. Medium-textured (loam) soils are ideal for soybean production. Heavy clay soils can lead to difficulties in planting and emergence, but once emerged, soybeans are well adapted. Sandy or gravelly soils, which tend to be droughty during the growing season, are least suited to soybean production.

One of the common problems in the field production is the crust formation at the soil surface (Zebec et al., 2017; Špoljar et al., 2018; Vrandečić et al., 2019). In that conditions the young plants are very difficult to emergence becouse their cotyledons (VE growth phase) can not get to above the soil surface. That could be a huge problem for those soil types which are inclinable to crust formation (with higher clay share), because cotyledons can appear at the soil sufrace from 5 to 21 days after sowing. Thus, in row-spacing of 12.5 and 25 cm it is hard to do the row cultivation, and the air phase of the soil can be lack with O_2. In such conditions the growth and development of nitrogen fixators as *Bradyrhizobium japonicum* is decreased (Kristek et al., 2017; Jabborova et al., 2018).

Another problem in soybean production is weed control (Akter et al., 2016; Šermešić et al., 2016). According to Van Acker et al. (1993) a critical period of weed control lasting up to the fourth node growth stage (V_4), approximately 30 days after emergence, was adequate to prevent a yield loss of more than 2.5%

Close to maturity stage (R_7), cultivar Ika in this study was on average 103.1 cm high (1st September) and the different row-spacing influenced very significantly ($p < 0.01$) on the stem height. Naydenova & Georgieva (2019) found that soybean plant height of 28 cultivars varied from 53.4 cm (cultivar Romantica) to 106.5 cm (cultivar Onix) and on average it was 83.0 cm. In our study, at the last sampling date in September, the highest plants were found in 50 cm row-spacing (119.7 cm).

According to Croatian Bureau of Statistic (2018) average yield of soybean seed in 2018 was 2.8 t ha^{-1}. Thus the average yield (1.51 t ha^{-1}) in our study was less than the state average in 2018. Even though the highest yield (1.90 t ha^{-1}) was determined at 25 cm row-spacing, the plants grown in wider

Table 3. The number of plants at harvest and seed yield per plant and per unit area in 2018

Row-spacing, cm	No. plants m^{-2}	Seed yield per plant, g plant^{-1}	Seed yield, t ha^{-1}
12.5	41	8.65	1.70
25	32	12.15	1.90
50	17	12.12	1.00
70	15	19.79	1.43
Prosjek	26	13.17	1.51
$LSD_{0,05}$	3.3	5.278	0.733
$LSD_{0,01}$	4.6	ns	ns

Table 4. Pearson‘s correlation coefficient for soybean growth parameters during vegetation and seed yield in 2018 (n = 80)

	PH	FM	DM	SYP
1st June				
FM	0.349 ***			
DM	0.261 *	0.842 ***		
SYP	-0.712 ***	-0.134 *ns*	-0.034 *ns*	
SYH	0.507 ***	0.038 *ns*	-0.067 *ns*	-0.298 *
1st July				
FM	0.489 ***			
DM	0.489 ***	0.964 ***		
SYP	-0.229 *	0.111 *ns*	0.159 *ns*	
SYH	-0.270 *	-0.298 **	-0.311 **	-0.228 *
1st August				
FM	0.151 *ns*			
DM	0.428 ***	0.469 ***		
SYP	-0.051 *ns*	0.093 *ns*	-0.235 *	
SYH	-0.050 *ns*	-0.116 *ns*	0.018 *ns*	-0.228 *
1st September				
FM	0.421 ***			
DM	0.206 *	0.586 ***		
SYP	-0.156 *ns*	0.342 **	0.129 *ns*	
SYH	-0.422 ***	-0.445 ***	0.058 *ns*	-0.228 *

PH – plant height (cm plant^{-1}); FM – fresh matter plant^{-1}; DM – dry matter plant^{-1}; SYP – Seed yield plant^{-1}; SYH – Seed yield (t ha^{-1})

space (70 cm) resulted with the higher yield per plant (19.79 g plant^{-1}). For example, Nilahayati et al. (2019) found higher soybean seed yield per plant, on average 51.3 g plant^{-1}. In the study of study two row spacings (19 and 76 cm) and four seeding rates (247 000, 333 500, 420 000, and 506 500 seeds ha^{-1}), Schutte & Nleya (2018) found that emergence of soybean was greater at 19 cm row-spacing compared to 76 cm. According to Bing et al. (2015) reducing of light intensity through shade, will increase young pods or flowers abscission, lengthen internodes of soybean plant, decrease seed yield and increase plant lodging. Authors also stated that the nutrition area of soybean under low density (14 plants m^{-2}) was more than that under moderate and high densities condition (27 and 54 plants m^{-2}). This could be the reason of decreased seed yield per plant in small row-spacing the plants or our study.

Conclusion

Different row-spacing had very significant ($p < 0.01$) influence on plant height from June to September. The highest soybean stem was at 50 cm row-spacing at the beginning of September (119.7 cm in plant^{-1}). On average, the highest fresh and dry mattter acuumulation was determined in the period from 1st July to 1st August (R_3 to R_6 growth phase), when increment account total 90.73 g plant^{-1} and 26.60 g plant^{-1}, respectively. Generally, the average seed yield was 1.51 t ha^{-1}, with the seed yield per unit area being the highest at a row spacing of 25 cm (average 1.90 t ha^{-1}), which is compared to yields of other row-spacing were statistically significant at the $p < 0.05$ level.

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Received: June, 17, 2019; *Accepted:* August, 28, 2019; *Published:* June, 30, 2020