

## SOYA BEAN BIOMASS PRODUCTION UNDER DIFFERENT WATER REGIME CONDITIONS

Jela IKANOVIC<sup>1\*</sup>, Snezana JANKOVIC<sup>2</sup>, Vera POPOVIC<sup>3</sup>, Gordana KULIC<sup>1</sup>, Sveto RAKIC<sup>1</sup>, Gordana DRAZIC<sup>4</sup>

<sup>1</sup>University of Belgrade, Faculty of Agriculture, Serbia

<sup>2</sup>Institute for Science Application in Agriculture, Belgrade, Serbia

<sup>3</sup>Institute of Field and Vegetable Crops, Novi Sad, Serbia

<sup>4</sup>“Singidunum” University, “Futura”, Belgrade, Serbia

\*Corresponding author: jela@agrif.bg.ac.rs; bravera@eunet.rs

### Abstract

The paper investigates soya bean biomass production on brown forest soil (cambisol) under conditions of dry farming and irrigation. The experimental studies were carried out on brown forest soil in Mladenovac during 2011 and 2012. The subject-matter of this research was *Proteinka*, a domestic soya bean cultivar, grown under conditions of natural water regime and two irrigation variants. The results showed that irrigation had caused significantly larger plant height and pod mass per plant. In the biennial average, the best results were achieved with the second irrigation variant (three waterings). Therefore, what can be recommended for soya bean production under these agro ecological and soil conditions is three waterings with the amount of water higher than optimal. This irrigation system will lead to more favourable relative humidity of air, considering soya bean is equally sensitive to soil and air drought during gametogenesis.

**Key words:** *soya bean, natural water regime, irrigation, plant height, pod mass per plant*

### Introduction

The relationship between the soya bean and climatic factors is determined by the origin of the soya bean. The soya bean originates from Mandzuria, where there is a monsoon-type climate during the period of blooming and pod formation, i.e. the climate is hot with high relative humidity. In such climatic conditions, the soya bean gives high and stable yields (Popovi , 2010; Kolaric et al., 2014a, 2014b; Popovic et al., 2014). Modern production technologies, the imperative of which is economic efficiency, have set high standards not only in the way of biomass production, but also for the preservation of natural resources and protection of ecosystems. To fulfil these requirements, the results of numerous studies point to problems and limiting factors in soya bean production. Considering that the soya bean seed is a necessary component of quality forage feeds due to its high energy and easy digestibility, the aim of soya bean production is therefore the production of seeds with a high nutritional value. The most important components of the seed are proteins and oils. Environmental conditions significantly affect the ontogenesis and yields of the soya bean seed. The soya bean in Serbia is irrigated in a small number of areas, although most researchers point out there are more possibilities for crop irrigation in the most important agricultural areas (close to big rivers). Rational water management enables achieving maximum yields per unit water use, while preserving the environment and its sustainability, as Tolimir (2002) pointed out. This is the reason why all the studies on growing field crops under different soil moisture conditions are important, since their results not only contribute to the economic efficiency of the production, but they are also in line with the priority objectives of the EU agricultural policy, aimed at natural resources protection (European Union, 2000). The

soya bean is a plant specific for its water requirements. As pointed out by Al-Kaisi et al (2003), a lack of water causes lower yields, due to discarding of flowers and a relatively large decrease of fertilisation. Besides soil drought, air drought is also very unfavourable. In extreme conditions, more strata of the soya bean canopy lag behind, plant height decreases, as well as the photosynthetically active leaf area, therefore decreasing the size of the seed (Popovi , 2010; Popovic et al., 2012). There are several methods of drought management, ranging from genetics, breeding, selection, and zoning of certain cultivars to the application of numerous agricultural measures in soya bean production. Irrigation is the only measure that can solve drought problems (Miladinovi et al., 2008, a citation of: Bošnjak, 2001; An elkovi et al., 2001). Analysing the dynamics of water use per phenophase, Glamo lija (2012) emphasised that the soya bean absorbs the minimum amount of water during seed germination and emergence. In initial growth stages, water use is relatively small - only 0.5 l m<sup>2</sup> a day, although in the swelling stage the soya bean absorbs approximately 150% of its mass. Water use increases with later growth stages, achieving its maximum in the periods of pod formation and seed filling. In these periods plants absorb 8 l m<sup>2</sup> of water, which is about 70% of the total amount required. After that, water use gradually decreases. In the agro ecological conditions of Serbia, water regime in the period of the largest water use is not favourable in most production areas. The goal of this paper was to identify the effect of irrigation rates on key morphologic characteristics that determine soya bean biomass, such as plant height and the number of fertile pods per plant.

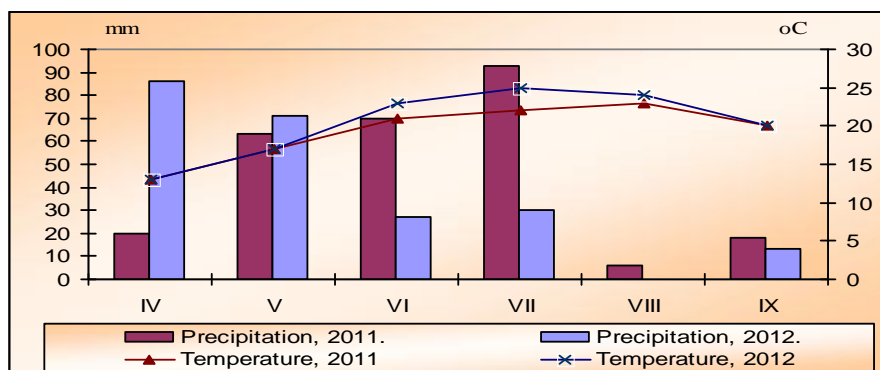
### **Materials and methods**

The experimental studies were carried out in the agro ecological conditions of Mladenovac on brown forest soil, as two-year block field trials (Hadživukovi , 1991) with three replications. Main plot area was 4,000 m<sup>2</sup>. The size of the experimental plot was 2,000 m<sup>2</sup>, and the size of the basic plot was 6 m<sup>2</sup>. Key morphological characteristics that directly determine soya bean biomass, such as plant height and the number of fertile pods per plant, were studied in relation to applied irrigation rates. The rates had been determined based on the average precipitation in critical periods and then compared with the actual plant requirements. According to the calculated model, two variants of irrigation were determined, comprising two and three waterings with 70 l of water each. The trials comprised three variants: control (variant 1 - no irrigation); two waterings (variant 2); and three waterings (variant 3) carried out in critical periods for soya beans, such as flowering - R1-R3, pod formation and growth - R3-R4, and seed formation and growth - R4-R6. The statistical analysis of the results was done with the analysis of variance. The variant without irrigation was used as a control variant, and the differences between each treatment were analysed with the LSD test, at the significance level of 0.05% and 0.01%

### **Meteorological conditions**

The water requirements of the soya bean are not the same during the whole growing season. They are lower in the first part of the growing season when vegetative parts are formed, increasing during the formation of generative organs and reaching its maximum during seed filling (Popovi , 2010).

Having analysed the weather conditions in 2011 and 2012, the authors made a conclusion the conditions were unfavourable for soya bean production. In both years, there was less precipitation during the growing season compared with the multi-year average for this production area, and significantly less precipitation than it was optimal for these growing conditions. This water regime was accompanied with very high air temperatures, unfavourable for soya bean production.



Graph. 1. Temperature ( $^{\circ}\text{C}$ ) and precipitation (mm) in the soya bean growing season, 2011-2012 (Meteorological station of Mladenovac)

In both years, there was less precipitation when compared with the multi-year average for the area of Mladenovac. The monthly distribution of precipitation in the growing season was different each year, and generally unfavourable for soya bean production. The amount of precipitation in 2011 was 270 mm, which was 84 mm less when compared with the multi-year average, while the precipitation deficit was 168mm. In the 2012 growing season, the amount of rainfall was 227 mm, being 127 mm less than the average, with the deficit of 186 mm (Table 1, Figure 1).

Table 1. Precipitation and plant water requirements, mm (Meteorological station of Mladenovac)

Year/Month	IV	V	VI	VII	VIII	IX	Sum
Requirements	50	75	90	90	95	30	430
2011	20	63	70	93	6	18	270
Deficit	-30	-12	-20	+3	-89	-12	-168
2012	86	71	27	30	0	13	227
Deficit	+36	-4	-63	-60	-95	-17	-186
Average	48	56	85	62	53	50	354
Deficit	-2	-19	-5	-28	-42	+20	-76

It should be noted also that pre-season precipitation (winter and early spring precipitation) in 2010/11 was 25mm less than the multi-year average. In the second year of research, a lack of precipitation in the same period was even higher, being 82 mm.

Table 2. Monthly and optimal air temperatures,  $^{\circ}\text{C}$  (Meteorological station of Mladenovac)

Year/Month	IV	V	VI	VII	VIII	IX	Average
2011	13	17	21	22	23	20	19.3
2012	13	17	23	25	24	20	20.3
Average	12	17	20	22	21	17	18.1
Optimal	12	15	20	20	21	16	17.3

In both years, the average monthly temperature in the growing season was higher than the multi-year average, by  $1.17^{\circ}\text{C}$  in 2011 and  $2.07^{\circ}\text{C}$  in 2012. During the summer months, there were particularly large deviations from the average temperature, and the soya bean was then in the generative stages of growth when it was very sensitive to high temperatures and low relative humidity (Table 2).

## Results and discussion

The results comprised key morphological characteristics, such as plant height and the number of fertile pods per plant, which directly determined soya bean biomass.

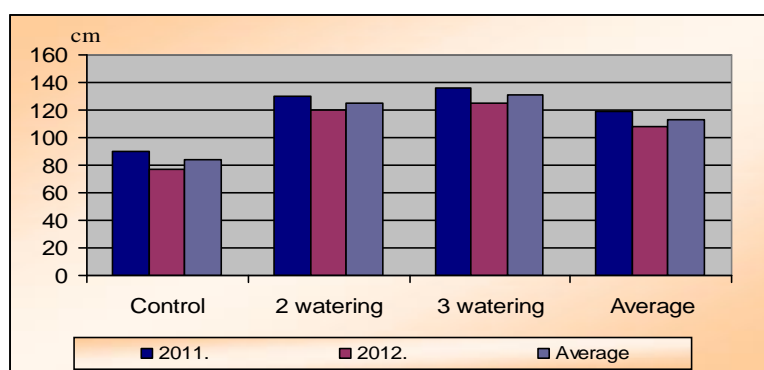
### Plant height

Soya bean height, as a cultivar trait, depends on agro ecological and soil conditions and it is subject to variation (Popovic et al., 2012). The two-year average height of the soya bean in all variants was 113.23 cm. The results showed that irrigation rates and soil water regime during the growing season affected soya bean growth significantly (Table 3).

Table 3. Plant height per variant, cm

Year	Variant 1 - Control	Variant 2 – two waterings	Variant 3 – three waterings	Average
2011	90.2	130.5	135.8	118.83
2012	77.1	120.4	125.4	107.63
Average	83.65	125.45	130.60	113.23
LSD of variants	0.05% = 1.788; 0.01% = 2.330			
LSD of years	0.05% = 1.622; 0.01% = 2.330			
LSD of years x variants	0.05% = 3.097; 0.01% = 4.182			

In the research period (2011-2012) irrigation helped the crops reach the average height of 125.45 cm and 130.60 cm, respectively, which was an increase of 49.70% and 56.13% compared to the control variant. The lowest stem height (77.1 cm) was recorded in arid 2012, in the variant of natural water regime. The crops were significantly lower in the control variant than in the variants with two and three waterings, and also lower compared to the first year. In 2012, the irrigated crops achieved the height of 120.40 cm, and 125.40 cm, respectively, which was a significant increase of 56.16% and 62.65% compared to the control variant.



Graph 2. Average plant height per variant, cm

In 2011, the irrigated crops reached the height of 130.50 cm, and 135.80 cm, respectively, which was a significant increase of 44.68% or 50.50% compared to the control variant. Under favourable conditions, soya beans form longer internodes and higher stems (Glamo lija et al., 2009). Some authors reported that soya bean growth depends on thermal conditions and soil moisture in the period from germination to the formation of the first 5-6 internodes. The impact of cropping practices on plant height is also significant.

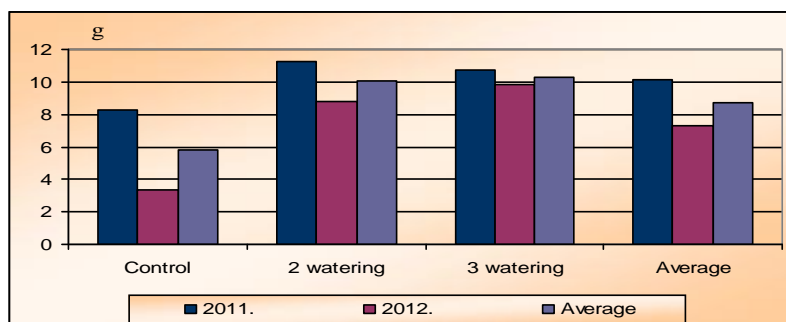
### Mass of fertile pods per plant

The two-year average mass of fertile pods per plant was 8.70g in all variations. The results showed that the water regime of soil during the growing season and irrigation rates had a very significant impact on this parameter (Table 4).

Table 4. The mass of pods with seed per plant, g

Year	Control	Two waterings	Three waterings	Average
2011	8.31	11.28	10.77	10.10
2012	3.34	8.82	9.83	7.30
Average	5.80	10.05	10.30	8.70
LSD of variants	0.05% = 0.0701; 0.01% = 0.0946			
LSD of years	0.05% = 0.1159; 0.01% = 0.1665			
LSD of years x variants	0.05% = 0.1214; 0.01% = 0.2539			

In 2011-2012, the average mass of fertile pods in the variants with two waterings (10.05 g), and three waterings (10.30g) was significantly higher than in the control variant (5.80 g), by 73.28% and 77.59%, respectively. The mass of fertile pods ranged from 8.82 g in 2012 to 11.28 g in 2011 in the variant with two waterings and from 9.83g in 2012 to 10.77g in 2011 in the variant with three waterings. The irrigated plants had a significantly greater mass of fertile pods. The smallest mass of fertile pods per plant was recorded in the control variant (3.34g) in the second year of research that was rather arid, so it can be concluded that water regime plays a significant role in pod formation and the number of pods. As the number of waterings increased, the value of the studied parameter also increased, by 164.07% and 194.31%, respectively.



Graph.3 Mean mass of fertile pods per plant, g

In 2011, the irrigated crops had the pod mass of 11.28 g, and 10.77 g, which was a significant increase of 35.74% and 29.60%, respectively, compared to the control variant. Crops exposed to drought produce fewer seeds per pod, had smaller seed mass, resulting in lower yields (Popovi , 2010, Popovic et al., 2012).

### Conclusions

This research on soya bean biomass production under conditions of different soil moisture shows the following:

Production of soya bean biomass on brown forest soil type (cambisol) under the condition of irrigation is more justifiable than dry farming, since the soya bean is sensitive on both soil and air drought, especially in the period of gametogenesis.

In the period 2011-2012, the irrigated crops reached 125.45 cm and 130.60 cm of height, which is an increase of 49.70% and 56.13%, respectively, when compared to the control variant.

In 2011-2012, the average mass of fertile pods per plant in the variant with two waterings (10.5 g), and three waterings (10.30 g) was significantly higher than in the control variant (5.80 g), by 73.28 and 77.59%.

Observed by years, variations in plant height and mass of pod were lower in the irrigated than in non-irrigated crops, showing the importance of this cropping practice for soya bean growth and pod formation. It is important for putting into practice in order to maximise the genetic potential of plants and have rational and economical production.

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