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Original scientific article

DECREASE OF YIELD COMPONENTS AND MORPHOLOGICAL TRAITS OF SOYBEAN FULL-SIBS UNDER DROUGHT CONDITIONS

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Soybean, as a plant species, is native to regions with conditions favourable of humidity and temperatures for its growth and development. The expansion of the soybean growing area resulted in requirements of varieties with higher tolerance and more stable grain yield under drought conditions. In order to develop high yielding varieties, the method of full-sib (FS) selection was applied in this study, as one of many methods of recurrent selection. The basic principle of recurrent selection is a cyclic selection, with the aim to accumulate favourable alleles. Three most yielding $F_{2:3}$ sister lines obtained from the crossing combination of varieties Kunitz and Kador, were used for two combinations. Progenies of two FS crossing combinations were tested in two locations during two years (2011 with more favourable and 2012 with less favourable precipitation distribution). The values of grain yield per plant, the most important components of yield and morphological traits decreased under less favourable conditions. The highest decrease was recorded in the number of pods and the number of grains per plant, whereas the lowest decrease was found for the 1000-grain weight. Regardless of the relatedness of the tested material, significant differences in response to drought were observed not only between two FS progenies, but also within progenies of each combination. Soybean grain yield is a complex trait strongly affected by environmental conditions. Under unfavourable conditions, the reductions in the

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following traits were observed in progenies of two sister combinations: grain yield per plant (26.5-36.0% and 25.6-42.7%), number of pods per plant (18.6-33.0% and 12.6-38.2%) and the number of grains per plant (18.1-30.2% and 14.3-37.6%). Three progenies of FS crossings with the lowest yield reduction were identified as suitable initial material for the development of varieties with higher tolerance to drought conditions.

Keywords: soybean, full sib crossing, yield components, drought

INTRODUCTION

Soybean originates from the region with warm climate and sufficient water supply. Due to the expansion of the soybean growing region, new varieties with more favourable water status, capable to have satisfactory yields even under conditions with the water scarcity were developed in the process of selection under conditions with reduced amounts of water. It was observed at the end of the last century that agricultural production was performed in over 50% of arable lands with occasional or constant water deficits (MYERS *et al*., 1986). These areas have been increasing with global warming and ever faster climate changes. The amount of available water and their distribution during the growing season are major limiting factors in the production of soybean. Soybeans require 400-500mm precipitation during the growing season for the growth and development under conditions in Serbia.

Soybean breeding programmes, as other crops, are designed to create more superior genotypes than the existing varieties, primarily with the higher grain yield, and then better for all other significant traits for specific purposes and growing conditions. It is known that the number of pods per plant, the number of grains and the mass of 1000 grains are the most important components of soybean grain yield (DE BURIN and PEDERSEN, 2009; POPOVIC *et al*., 2016a). The grain yield per plant and the number of grains per plant are an efficient criterion in soybean breeding programs for high grain yield (SUDARIC *et al*., 2002). The development of a new variety begins with the choice of the parents. This step is extremely important and can be a limiting factor for the whole process (CARPENTERI-PIPOLO *et al*., 2000; LAKIĆ *et al*., 2018; 2019). The segregating population develops after chosen parents crossing. Classical (phenotypic) selection methods, which can be modified in various ways, are still successfully used in modern breeding programs. In order to accumulate favourable alleles, most often to improve quantitative traits, recurrent selection methods are applied. The use of recurrent selection in self-pollinated species such as soybean started in the 1960-is (VELLO and NAZATO, 2017). A common feature of all recurrent selection methods is a selection and recombination of a small number of superior progenies for the next selection cycle (STOJKOVIĆ *et al*., 2008). Recurrent selection in soybean has been used to increase variability of the initial population (ALLIPADRINI and VELLO, 2004) or to improve a desired trait: grain size (TINIUS *et al*., 1991), increase in protein content (BRIM and BURTON, 1997), and grain oil content (BURTON and BRIM, 1981; FENG *et al*., 2004), to improve the quality of soybean oil i.e. the increase of oleic acid content in grain (BURTON *et al*., 1983), prolong the grain filling (HANSON, 1992) and increase of grain yield (KENWORTHY and BRIM, 1979; POSADAS, 2017). Due to the fact that the sufficient number of crosses necessary for certain cycles of recurrent selection is difficult to achieve in soybean, new varieties are predominantly developed from the progenies of two parent crosses. Approximately only 10% of all American soybean varieties were realized using recurrent selection methods (MIKEL *et al*., 2010). The method of full-sib selection, used in this study, is one of the methods of recurrent selection.

The aim of this investigation is to identify the initial material with the lowest changes in the main components of grain yield and morphological characteristics that affect the yield in unfavorable water supply, for selection of varieties with increased drought tolerance.

MATERIALS AND METHODS

The material used in this study was formed by crossing two varieties, as the initial parents, to develop high yielding inbred lines. *Kunitz*, the American variety a maternal parent in this cross combination is the first registered soybean variety lacking Kunitz-trypsin inhibitor in mature grains (BERNARD *et al*., 1991). The variety is classified into the III maturity group. Due to the longer vegetation, varieties from this maturity group, they are less represented and less sown in Serbia. It is most grown for silage (POPOVIĆ *et al.*, 2016b). *Kador*, a variety of standard grain quality, used as a male parent, was developed by the French seed company Semundo, belongs to the II maturity group. This variety has been tested under our conditions and proved to be a high yielding variety. Both parents are indeterminate varieties, which are more suitable for our growing conditions. The type of stem growth is a varietal trait that contributes to the grain yield response under specific growing conditions (QUATTARA and WEAVER, 1994; KILGORE-NORQUEST *et al*., 2000). Crossing was done manually, with the removal of unopened anthers from the maternal parent's flowers. The success of crossing depends on the skill of the person performing the procedure, but to a great extent, on the environmental conditions, primarily temperature, soil moisture and air humidity (AGRAWAL *et al*., 2001).

Based on morphological markers, F_1 individual plants were identified and their seed was used for developing segregating population. Forty-eight individual F_2 plants, marked as 1 – 48, were selected. The seed set of each F_2 plant was divided into two quantities, the first was used to set up a field experiment for yield testing, and the second was preserved to form sister (FS) cross combinations after yield testing and selection of the most suitable ones.

One-year trial was set up according to the RCB design in two locations (Zemun Polje and Indjija). Three F_3 lines originated from F_2 plants L6, L30 and L38 with the best rank of grain yield per plant were selected. FS crosses were made on F_3 lines which originating from the preserved seed of 6, 30 and 38 F_2 plants. Two traits were used as markers to identify successfully performed crosses: the colour of the flower and the colour of pubescences. L30 and L38 had purple and white flowers, and grey and yellow pubescences, whereas L6 had white flowers and yellow pubescences. The pollen for the male component was taken from randomly selected plants from the corresponding F_3 line, taking into account that the traits used as the marker were in the phenotypically dominant form (plants with purple flowers and/or yellow pubescence), the mother plants were with the same properties in recessive form. Plants originating from sister crossings were grown and all plants that did not express dominant traits of the male component were eliminated. Plants with successfully performed sister crosses (FSF_1) were grown to maturation. There were 10 and 15 FSF_1 plants in the L38 x L6 and L6 x L30 combination, respectively. In the following season, progenies of sister crosses ($FSF_{1:2}$) were grown and thus enough seeds were provided for yield testing. Two trials were set up - one for each combination -

according to the randomised complete-block (RCB) design, with three replications and two locations (Indjija and Zemun Polje) for two years (2011 and 2012). The elementary plot consisted of two 5-m rows, with the inter-row distance of 0.5 m and the within-row plant distance of about 4 cm, which corresponds to a crop density of approximately 400.000 plants ha^{-1}. In addition to grain yield per plant, the following traits were also measured: main stem height, the number of nodes on the main stem, the number of pods per plant, the number of grains per plant and 1000-grain weight. All measures were done on 40 plants per replication, whereas 1000-grain weight was established from samples drawn from each elementary plot.

Obtained data were processed for each trial separately by the tree-factor analysis of variance with divided sub-plots according to HADŽIVUKOVIĆ (1991). Data were processed by the MSTAT program, Experiment model 13 (MSTAT DEVELOPMENT TEAM, 1989), which involves the randomised complete-block (RCB) design for the factor A - with the factor B and the factor C as a split plot with three errors. The split-plot arrangement estimates observed treatments with different precision, where each factor has its own error. Each subsequent division has a larger number of units, while the error decreases. Significance of differences between progenies was tested by Fisher's LSD test.

RESULTS AND DISCUSION

For the growth and development of soybeans in the conditions of our country, 390-520 mm of precipitation is needed, where the distribution by months is of crucial importance (BOŠNJAK, 2001). According to precipitation distribution during to growing season, there was a lack of precipitation in both years, but 2011 was a more favorable year compared to 2012. Periods of water deficit in 2011 were less pronounced and this year can be considered more favorable than 2012.

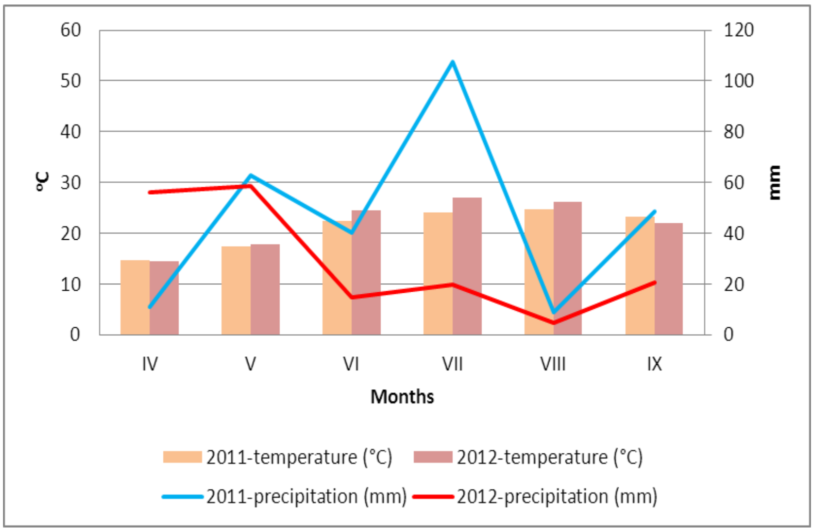

Figure 1. Average monthly temperatures and precipitation Zemun Polje 2011 and 2012

At the location of Zemun Polje, a period of drought was observed in August 2011, while during 2012, soybean plants were exposed to drought from June to August, during flowering and grain filling (Figure 1). At the location of Indjija, distribution of precipitation was more favorable in both years, but in 2012, despite sufficient precipitation in July, in August during the grain filling there was a dry period more pronounced than in 2011 (Figure 2).

Such conditions resulted in the reduction of values of studied morphological traits and yield components of soybean. Gained data were processed by the selected model of the analysis of variance, where the effects of the year (Y) were at the first division, effects of location (L) at the second division and effects of FS progenies were at the last division (P), for the better accuracy in determining differences with respect to close relatedness of the tested material. Table 1 shows mean squares from the third division of the analysis of variance (with significance according to the F test) and coefficients of variation.

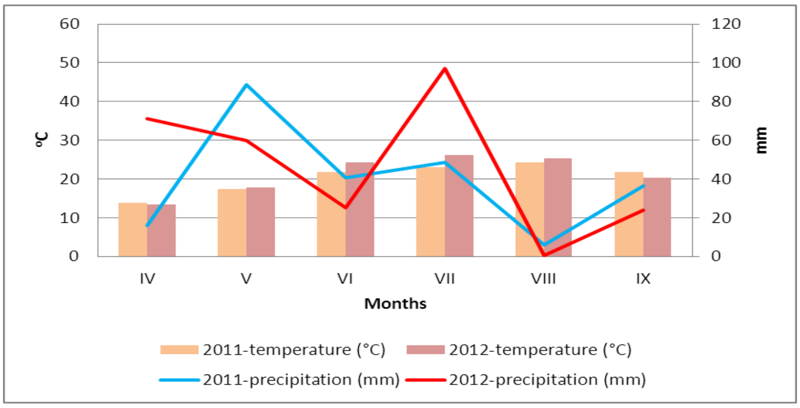

Figure 2. Average monthly temperatures and precipitation Indjija 2011 and 2012

Statistical differences at 0.01 significance level were determined between observed $FSF_{1:2}$ progenies of both sister combinations for all observed traits and most interactions. Only for the number of nodes in L38 x L6 $FSF_{1:2}$ progenies, interactions Y x P and L x P did not show significant differences and the Y x L x P interaction showed differences at significance level of 0.05. Despite the high relatedness of observed $FSF_{1:2}$ soybean progenies, there is variability within the studied traits. The 1000-grain weight was the most uniform trait with the least variation of all treated traits ($FSF_{1:2}$ progenies of the combinations L6 x L30 CV= 1.33% and L38 x L6 CV= 1.23 %). The stem height also showed low variability ($FSF_{1:2}$ progenies of the combinations L6 x L30 CV=2.59% and L38 x L6 CV=3.23%). The variability in the number of nodes per plant was similar to the variability in the stem height ($FSF_{1:2}$ progenies of the combinations L6 x L30 CV=2.80% and L38 x L6 CV=3.63%). The number of pods per plant showed greater variation compared to the previous traits ($FSF_{1:2}$ progenies of the combinations L6 x L30 CV=6.95% and L38 x L6 CV= 6.32%). MALEK *et al*. (2014) recommended the number of grains per plan as the best trait, and the number of pods as additional trait for the selection of adaptable genotypes in oscillating weather conditions. The variability in the number of grains was consistent with the variability of the number of pods ($FSF_{1:2}$ progenies of the combinations L6 x L30 CV= 6.81% and L38 x L6 CV= 6.02%). The highest value of the coefficient of variability in this experiment was obtained for the grain yield per plant into $FSF_{1:2}$ L6 x L30 progenies (CV= 8.49%), whereas it was lower for $FSF_{1:2}$ L38 x L6 progenies (CV= 5.53%), VARNICA *et al*. (2018) also found the greatest variability of this trait between different varieties, especially in less favorable conditions (CV=27.8%).

Table 1. Mean square values from analyses of variance (third division) and coefficients of variation of the estimated traits of ful sib ($FSF_{1:2}$) soybean progenies

Source		Traits		
$FSF_{1:2}$ L6 xL30	df	Plant height (cm)	Number of nodes	Number of pods
Progeny (P)	14	559.38**	4.19**	53.080**
Year x progeny (YxP)	14	52.33**	1.40**	26.885**
Location x progeny (LxP)	14	206.78**	1.76**	19.363**
Year x location x progeny (YxLxP)	14	47.29**	1.33**	13.639**
Error	112	8.17	0.23	5.322
		CV=2.59%	CV=2.80%	CV=6.95%
$FSF_{1:2}$ L6 xL30		Number of grains	1000 grains weight (g)	Yield per plant (g)
Progeny (P)	14	274.666**	567.992**	13.19**
Year x progeny (YxP)	14	156.878**	209.424**	6.42**
ocation x progeny (LxP)	14	114.594**	272.155**	4.51**
Year x location x progeny (YxLxP)	14	68.721**	72.577**	3.19**
Error	112	24.797	4.964	1.09
		CV= 6.81%	CV= 1.33%	CV= 8.49%
$FSF_{1:2}$ L38 xL6	df	Plant height (cm)	Number of nodes	Number of pods
Progeny (P)	9	346.06**	6.48**	53.78**
Year x progeny (YxP)	9	94.60**	1.21	46.37**
Location x progeny (LxP)	9	69.96**	1.07	24.18**
Year x location x progeny (YxLxP)	9	49.01**	2.17*	11.31**
Error	72	14.67	0.40	4.70
		CV=3.23%	CV=3.63%	CV= 6.32%
$FSF_{1:2}$ L38 xL6		Number of grains	1000 grains weight (g)	Yield per plant (g)
Progeny (P)	9	342.18**	644.84**	8.24**
Year x progeny (YxP)	9	173.35**	300.77**	6.58**
Location x progeny (LxP)	9	108.34**	118.64**	3.50**
Year x location x progeny (YxLxP)	9	65.03**	58.13**	2.91**
Error	72	22.33	4.22	0.53
		CV= 6.02%	CV= 1.23%	CV= 5.53%

*significant at the 5% probability level
**significant at the 1% probability level

The average values of the main stem height of tested $FSF_{1:2}$ progenies and the decrease of the height under more unfavourable conditions, which is presented in absolute values and %, are shown in Table 2.

Table 2. Plant height of soybean progenies from two FS combinations

FSF1:2 L6 xL30					FSF1:2 L38 X L6				
Progeny	2011 cm	2012 cm	Decreasing		Progeny	2011 cm	2012 cm	Decreasing	
			cm	%				cm	%
1	112.55	100.50	12.06	10.7	1	125.38	110.64	14.73	11.8
2	112.30	102.29	10.01	8.9	2	133.58	120.43	13.15	9.8
3	103.02	91.32	11.71	11.4	3	147.56	123.16	24.40	16.5
4	128.36	108.95	19.41	15.1	4	130.73	114.42	16.30	12.5
5	118.44	104.52	13.02	11.8	5	137.92	115.21	22.72	16.5
6	132.18	111.01	21.17	16.0	6	137.24	121.04	16.20	11.8
7	120.66	105.98	14.68	12.2	7	136.70	112.56	24.14	17.7
8	117.31	104.39	19.92	11.0	8	129.00	108.75	20.25	15.7
9	119.16	102.49	16.67	14.0	9	141.39	118.54	22.85	16.2
10	113.10	96.07	17.03	15.1	10	139.54	114.98	24.57	17.6
11	113.26	95.74	17.52	15.5					
12	119.54	103.79	15.75	13.2					
13	106.72	94.71	12.01	11.3					
14	127.73	108.72	19.02	14.9					
15	128.38	107.73	20.63	16.1					
Average	118.18	102.54	15.63	13.2	Average	135.90	115.97	19.93	14.7
$Lsd_{0.05}$=2.313 $Lsd_{0.01}$=3.059					$Lsd_{0.05}$=3.118 $Lsd_{0.01}$=4.138				

The progeny 3 of the FS combination L6 x L30 had the lowest stem height in $FSF_{1:2}$ progenies in both years (103.02 cm and 91.32 cm), whereas the highest stem was recorded in the progeny 6 (132.18 cm and 111.01 cm). In $FSF_{1:2}$ L38 x L6 progenies, the lowest height in a more favourable year was recorded in the progeny 1 (125.38 cm), whereas the progeny 8 had the lowest height (108.75 cm) in the less favourable year. The highest stem in both years was detected in the progeny 3 (147.56 cm and 123.16 cm). All differences in the stem height in the year with a more favourable distribution of precipitation during the growing period compared to the less favourable year were statistically significant at the probability level of 0.01. A decrease in the stem height below 10% in less favourable year (2012) was shown by one $FSF_{1:2}$ progeny from each cross combination, both designated with the number 2.

Soybean stem height depends on the number of nodes and the length of the internodes (KU *et al*., 2013). Decreasing of soybean main stem height is influenced by reduced internode length and number of nodes (FREDERICK *et al*., 2001). Under less favorable conditions in 2012, the number of nodes was lower with statistically significant differences in all progenies (Table 3).

Table 3. Number of nodes per plant of soybean progenies from two FS combinations

	$FSF_{1:2}$	L6 xL30				$FSF_{1:2}$	L38 X L6		
Progeny	2011	2012	Decreasing		Progeny	2011	2012	Decreasing	
			nodes	%				nodes	%
1	17.53	14.62	2.92	16.6	1	18.67	16,.64	2.03	10.9
2	18.48	16.70	1.78	9.6	2	18.84	17.99	0,85	4.5
3	17.65	16.05	1.60	9.1	3	19.67	17.23	2.44	12.4
4	18.43	16.63	1.80	9.8	4	17.42	15.78	1.64	9.4
5	18.78	16.17	2.61	13.9	5	18.02	15.49	2.52	14.0
6	17.10	14.98	2.11	12.3	6	19.16	16.66	2.51	13.1
7	18.58	16.33	2.25	12.1	7	18.57	14.50	4.06	21.9
8	17.98	15.41	2.58	14.3	8	18.03	15.94	2.09	11.6
9	18.02	16.22	1.80	10.0	9	19.26	16.54	2.71	14.1
10	18.34	17.37	0.97	5.3	10	18.85	17.07	1.78	9.5
11	17.43	15.16	2.67	13.0					
12	18.44	15.23	3.21	17.4					
13	16.95	15.16	1.79	10.6					
14	17.84	15.18	2.66	14.9					
15	18.13	16.31	1.82	10.0					
Average	17.98	15.83	2.14	11.9	Average	18.65	16.38	2.26	12.14
Lsd $_{0.05}$=0.384 Lsd $_{0.01}$=0.507					Lsd $_{0.05}$=0.517 Lsd $_{0.01}$=0.687				

In 2011 within $FSF_{1:2}$ L6 x L30 progenies the average number of nodes was 17.98, and in 2012 15.83, while within $FSF_{1:2}$ L38 x L6 progenies were 18.65 (in 2011) and 16.38 (in 2012). Nominal values of the reduction in the number of nodes in the year with the pronounced periods of drought were statistically at the level of significance of 0.01 in all progenies of both full sibs. The smallest decrease in the number of nodes was recorded in the progeny 2 from the FS combination L38 x L6 (by 4.5%) and in the progeny 10 from L6 x L30 (5.3%). The number of pods per plant in more favourable year (2011) ranged from 31.53 to 42.40, an average of 38.37 in $FSF_{1:2}$ L6 x L30 progenies. The corresponding values in less favourable year (2012) were 25.49-31.07, on average 27.94. On the other hand, these values in $FSF_{1:2}$ L38 x L6 were 35.72-46.13, on average 40.06 under more favourable conditions and 24.43-31.22 under less favourable conditions.

The range of reductions in the number of pods per plant was from 5.81 to 13.57 in $FSF_{1:2}$ L6 x L30 and from 4.50 to 16.49 in $FSF_{1:2}$ L38 x L6 with a statistically significant level of 0.01 of all tested progenies (Table 4). Progenies $FSF_{1:2}$ 1 with 18.6% and 7 with 12.6% in FSF1: 2 L6 x L30 and $FSF_{1:2}$ L38 x L6 (respectively) had the lowest reduction in the number of pods under less favorable conditions. Reduction of pods per plant according to the results of MIMI *et al*. (2016) ranged widely from 15% to 51%.

Table 4. Number of pods per plant of soybean progenies from two FS combinations

FSF$_{1:2}$ L6 xL30					FSF$_{1:2}$ L38 X L6				
Progeny	2011	2012	Decreasing		Progeny	2011	2012	Decreasing	
			pods	%				pods	%
1	31.53	25.67	5.81	18.6	1	43.16	26.67	16.49	38.2
2	38.64	26.08	12.55	32.5	2	41.53	29.47	12.07	29.1
3	37.51	27.84	9.67	25.8	3	39.00	24.43	14.57	37.3
4	41.14	27.76	13.57	33.0	4	39.38	30.84	8.54	21.7
5	38.05	25.95	12.10	31.8	5	40.9	29.69	11.00	27.0
6	40.58	30.00	10.58	26.1	6	37.07	25.51	11.56	31.2
7	40.00	27.79	12.20	30.5	7	35.72	31.22	4.50	12.6
8	39.84	29.94	9.90	24.8	8	37.69	29.27	8.42	22.4
9	36.79	28.93	7.87	21,4	9	40.21	26.38	13.83	34.4
10	37.81	26.56	11.25	29.8	10	46.13	30.58	15.56	33.7
11	34.79	25.49	9.31	26.8					
12	38.31	29.09	9.22	24.1					
13	42.40	31.07	11.33	26.7					
14	37.82	27.69	10.12	26.8					
15	40.31	29.39	10.92	27.1					
Average	38.37	27.94	10.43	27.2	Average	40.06	28.41	11.5	29.1
Lsd $_{0.05}$=1.866 Lsd $_{0.01}$=2.486					Lsd $_{0.05}$=1.245 Lsd $_{0.01}$=2.341				

The number of grains per plant amounted to 72.77-95.72 and 53.85-69.48 in progenies FSF$_{1:2}$ L6 x L30 in 2011 and 2012, on average 83.66 and 62.25, respectively. The corresponding values for progenies of FSF$_{1:2}$ L38 x L6 were 82.55-104.22 and 56.31-69.06, on average 91.65 and 64.56 (Table 5).

The reduction in the number of grains in less favourable year was mainly consistent with the reduction in the number of pods. Thus, the lowest reduction in the number of grains in progenies of both sister combination of crosses was in the same FSF$_{1:2}$ progenies in which the lowest decrease in the number of pods was: FSF$_{1:2}$ L6 x L30, progeny designated with the number 1 (decrease by 13.18 grains, 18.1%) and FSF$_{1:2}$ L38 x L6 progeny number 7 (decrease by 11.90 grains, 14.3%).

The 1000-grain weight was the most uniform trait with the least reaction under unfavourable conditions. This is in agreement with results published by DESCLAUX *et al*. (2000).The average values for both combinations of FSF$_{1:2}$ progenies were very approximate and amounted to 173.69g and 173.05g in 2011 and to 158.44g and 158.49g in 2012 (Table 6).

Table 5. Number of grains per plant of soybean progenies from two FS combinations

FSF1:2 L6 xL30					FSF1:2 L38 X L6				
Progeny	2011	2012	Decreasing		Progeny	2011	2012	Decreasing	
			grains	%				grains	%
1	72.80	5.61	13.18	18.1	1	92.18	57.47	34.71	37.6
2	84.17	60.76	23.41	27.8	2	95.65	67.84	27.81	29.1
3	80.34	58.82	21.51	26.8	3	88.49	56.84	31.65	35.8
4	87.64	62.23	25.37	28.9	4	93.39	71.63	21.76	23.3
5	84.02	58.62	25.40	30.2	5	96.03	69.06	26.97	28.1
6	86.03	66.41	19.62	22.8	6	82.55	56.31	26.25	31.8
7	88.74	65.71	23.03	26.0	7	82.99	71.08	11.90	14.3
8	88.24	67.89	20.35	23.1	8	88.60	67.40	21.21	23.9
9	80.90	64.59	16.31	20.2	9	92.37	59.82	32.55	35.2
10	83.15	61.12	22.03	26.5	10	104.22	68.10	36.11	34.7
11	72.77	53.85	18.91	26.0					
12	83.46	61.74	21.73	26.0					
13	95.72	69.48	26.24	27.4					
14	79.30	59.44	19.86	25.5					
15	87.59	63.58	24.02	27.4					
Average	83.66	62.25	21.40	25.4	Average	91.65	64.56	27.09	29.6
Lsd $_{0.05}$=4.028 Lsd $_{0.01}$=5.327					Lsd $_{0.05}$=3.846 Lsd $_{0.01}$=5.105				

Table 6. 1000 grain weight of soybean progenies from two FS combinations

FSF1:2 L6 xL30					FSF1:2 L38 X L6				
Progeny	2011 g	2012 g	Decreasing		Progeny	2011 g	2012 g	Decreasing	
			g	%				g	%
1	163.42	147.11	16.31	10.0	1	181.56	170.12	11.44	6.3
2	167.93	159.05	8.88	5.3	2	171.92	161.09	10.84	6.3
3	173.08	154.86	18.22	10.5	3	165.32	163.87	1.45	0.9
4	166.54	149.63	16.91	10.2	4	165.69	132.97	32.72	19.7
5	181.76	170.53	11.22	6.2	5	173.87	158.88	14.98	8.6
6	170.86	155.32	15.54	9.1	6	176.31	165.32	10.99	6.2
7	174.30	160.16	14.13	8.1	7	170.80	154.46	16.34	9.6
8	176.47	165.37	11.10	6.3	8	178.59	157.51	21.09	11.8
9	184.84	163.84	20.99	11.4	9	174.38	166.02	8.36	4.8
10	180.36	166.52	13.84	7.6	10	172.09	154.64	17.45	10.1
11	173.88	158.55	15.32	8.8					
12	165.19	154.34	10.85	6.6					
13	181.51	157.56	23.95	13.2					
14	165.90	152.64	13.27	8.0					
15	179.32	161.02	18.29	10.2					
Average	173.69	158,44	15.26	8.8	Average	173.05	158.49	14.55	8.4
Lsd $_{0.05}$=1.802 Lsd $_{0.01}$=2.383					Lsd $_{0.05}$=1.672 Lsd $_{0.01}$=2.219				

The average decrease in 1000-grain weight was only by 8.8% and 8.4%. The lowest decrease in the value of this trait due to unfavourable precipitation distribution was recorded in $FSF_{1:2}$ L6 x L30, progeny 2 (5.3%) and in $FSF_{1:2}$ L38 x L6, progeny 3 (0.9%), whose decrease of only 1.45g was not statistically significant.

Grain yield, a complex trait, a result of a response of yield components to the effects of environmental conditions, decreased statistically very significantly in a less favourable year in all observed full sibs (Table7).

Table 7. Grain yield per plant of two FS soybean progenies

	$FSF_{1:2}$ L6 xL30					$FSF_{1:2}$ L38 X L6			
Progeny	2011 g	2012 g	Decreasing		Progeny	2011 g	2012 g	Decreasing	
			g	%				g	%
1	12.08	8.64	3.44	28.4	1	16.99	9.73	7.26	42.7
2	13.75	9.79	3.97	28.8	2	16.43	10.74	5.49	33.4
3	13.99	8.99	5.00	35.7	3	14.63	9.01	5.63	38.5
4	13.90	9.52	4.38	31.5	4	15.49	9.35	6.14	39.6
5	15.26	9.94	5.32	34.8	5	16.74	10.95	5.78	34.5
6	14.77	10.30	4.47	30.3	6	14.47	9.25	5.23	36.1
7	15.47	10.61	4.86	31.4	7	13.68	9.89	3.79	27.7
8	16.07	11.14	4.93	30.7	8	15.86	11.80	4.06	25.6
9	14.61	10.74	3.87	26.5	9	16.13	9.85	6.27	38.9
10	14.62	10.06	4.56	31.2	10	18.03	10.48	7.55	41.9
11	12.47	8,76	3.71	29.8					
12	13.94	9,51	4.42	31.7					
13	17.35	11.22	6.14	35.4					
14	12.85	9.45	3.41	26.5					
15	15.96	10.22	5.75	36.0					
Average	14.74	9.93	4.55	31.4	Average	15,.9	10.13	5.72	36.1
Lsd $_{0.05}$=0.843 Lsd $_{0.01}$=1.114					Lsd $_{0.05}$=0.592 Lsd $_{0.01}$=0.786				

The average grain yield per plant ranged from 12.08g to 17.35g under favourable growing conditions and from 8.64g to 11.14g under less favourable conditions for progenies of $FSF_{1:2}$ L6 x L30. The corresponding values for the progenies of $FSF_{1:2}$ L38 x L6 amounted to 13.68-18.03g in 2011 and 9.01-11.80g in 2012. The lowest yield reduction of 26.5% was recorded in $FSF_{1:2}$ L6 x L30, progenies 9 and 14, whereby the progeny 9 had higher yields. The corresponding value in $FSF_{1:2}$ L38 x L6 of 25.62% was recorded in the progeny 8. According to the results of FREDERICK *et al*., (2012) and SADEGHIPOUR (2012), the reduction in soybean grain yield in different drought conditions varied from 2% to 50%. KOBAREI *et al.* (2011), reported 43-44% reduction in soybean yield under stressful conditions compared to normal conditions. Similar results were reported by FLAJŠMAN *et al*. (2019).

CONCLUSIONS

As material in this paper, the progenies of two full sibs obtained by crossing three sister lines were used. One of them is the parent component in both combinations. Regardless relatedness, progenies of both FS combinations expressed variability determined by coefficients of variation for all observed traits. Compared to other properties, the variability of the mass of 1000 grains was the smallest. Somewhat higher variations were found in stem height and number of nodes, while the largest variations were determined in number of pods and number of grains. Variation of grain yield per plant of the FS combination with the larger number, progenies $FSF_{1:2}$ L6 x L30 reached the highest value in the experiment. Progenies with the smallest reduction in grain yield per plant, 9 and 14 in FSF1:2 L6 x L30 and the progeny 8 in FSF1:2 L38 x L6 can be recommended as starting material adequate for selection of varieties with greater tolerance to drought conditions.

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REFERENCES

AGRAWAL, A.P., R.L., RAVIKUMAR, P.M., SALIMATH, S.A., PATIL (2001): Improved method for increasing the efficiency of hybridization in soybean. Indian J. Genet., *61* (1): 76-77.

ALLIPRANDINI, L.F., N.A., VELLO (2004): Heritability and correletions among traits in four-way soybean crosses. Euphytica, *136*: 81-91.

BERNARD, R.L., T., HYMOWITZ, C.R., CREMENS (1991): Registration of “Kunitz” soybean. Crop. Sci., *31*: 232-233.

BOŠNJAK, D.J. (2011). Soybean irrigation in single crop, second crop and stubble crop planting. In: MILADINOVIĆ, J., M., HRUSTIĆ, M., VIDIĆ (eds) Soybean. Institute of Field and Vegetable Crops, Novi Sad and Sojaprotein, Bečej, Grafika, Novi Sad: 315-342.

BRIM, C.A., J.W., BURTON (1979): Recurent selection in soybeans. II. Selection for increased percent protein in seeds. Crop Sci., *19*: 494-498.

BURTON, J.W., C.A., BRIM (1981): Recurent selection in soybeans. III. Increased percent oil in seeds. Crop Sci., *21*: 31-34.

BURTON J.W., R.F., WILSON, C.A., BRIM (1983): Recurent selection in soybeans. IV. Selection for increased oleic acid percentage in seed oil. Crop Sci., *23*: 744-747.

CARPENTIERI-PIPOLO, V., A.E., PIPOLO, F.A., SILVA, M.R, PETEK (2000): Soybean parent selection based on genetic diversity. Braz. Arch. Biol. Technol., *43*(3): 295-300.

DE BURIN, J.L., P., PEDERSEN (2009): Growth, yield and yield component changes among old and new soybean cultivars. Agronomy Jour., *101*(1): 124-130.

DESCLAUUX, D., T., HUYNH, P., ROUMET (2000): Identification of soybean plant characteristics that indicate the timing of drought stress. Crop Sci., *40*:716-722.

FENG, L., J.W., BURTON, T.E., CARTER JR., V.R., PANTALONE (2004): Recurrent half-seeb selection with testcross evaluation for increased oil content in soybean. Crop Sci., *44*: 63-69.

FREDERICK, J.R., C.R., CAMP, P.J., BAUER (2001): Drought-stress effects on branch and mainstream seed yield and yield components of determinate soybean. Crop Sci., *41*(3): 759-763.

FLAJŠMAN M., I., ŠANTAVEC, A., KOLMANIČ, K., KOŠMELJ, D., KOCJAN AČKO (2019): Agronomic performance and stability of seed, protein and oil yields of seven soybean cultivars determined in field experiments in Slovenia. Genetika, Belgrade, *51* (1): 31-46.

HADŽIVUKOVIĆ, S. (1991): Statistički metodi. Poljoprivreni fakultet. Institut za ekonomiku poljoprivrede i sociologiju sela. Novi Sad.

HANSON, W.D. (1992). Phenotypic recurent selection for modified reproductive period in soybean. Crop Sci., *32*: 968-972.

KENWOTHY, W.J., C.A., BRIM (1979): Recurent selection in soybeans. I. Seed yield. Crop Sci., *19*:315-318.

KILGORE-NORQUEST, L., C.H., SNELLER (2000): Effect of Stem Termination on Soybean Traits in Southern U.S. Production Systems. Crop Sci., *40*:83-90.

KOBAREI, S., A., ETMINAN, R., MOHAMMADI, S., KOBAREE (2011): Effects of drought stress on yield and yield components of soybean. Annals of Biological Research, *2* (5):504-509.

KU, Y.S, W.K., AU-YEUNG, Y.L., YUNG, M.W., LI, C.Q., WEN, X. LIU, H.M., LAM (2013): Drought stress and tolerance in soybean. In: BOARD, J.E. (ed) A Comprehensive Survey of International Soybean Research - Genetics, Physiology, Agronomy and Nitrogen Relationships. Intech Open: 209-237.

LAKIĆ, Ž., Đ., GLAMOČLIJA, D., KONDIĆ, V., POPOVIĆ, S., PAVLOVIĆ (2018): Fodder plants and cereals in the function of protecting the land from degradation. Monograph. Faculty of Agriculture Banja Luka. ISBN 978-99938-93-47, p. 1 – 405. (in Serbian)

LAKIĆ, Ž., M., ANTIĆ, I., ĐURĐIĆ, V., POPOVIĆ (2019): Morphological caracteristics of alfalfa genotypes tolerant of low soil pH. Genetika, *51* (3): 907-922.

MALEK, M.A., M.Y., RAFII, M.S.S., AFROZ, U.K., NATH, M.M.A., MONDAL (2014): Morphological characterization and assessment of genetic variability, character association, and divergence in soybean mutants. DIKSIC, M. (ed) The Scientific World Journal, 968796.

MIKEL, M.A., H.H., SMITH, R.L., NELSON, B.W., DIERS (2010): Genetic diversity and agronomic improvement of North American soybean germplasm. Crop Sci., *50*:1219-1229.

MIMI, A., M., MANNAN, Q., KHALIQ, M., MIA (2016): Yield response of soybean (*Glycine max* L.) genotypes to water deficit stress. Bangladesh Agronomy Journal, *19* (2): 51-60.

MSTAT DEVELOPMENT TEAM (1989): MSTAT-C: A microcomputer program for the design, management and analysis of agronomic research experiments. Michigan State University, East Lansing.

MYERS, O., J.H., YOPP, M.R.S., KRISHNAMANI (1986): Breeding soybeans for drought resistance. Plant Breeding Review, *4*: 203-243.

POPOVIC, V., M., TATIC, V., SIKORA, J., IKANOVIC, G., DRAZIC, V., DJUKIC, B., MIHAILOVIC, V., FILIPOVIC, G., DOZET, LJ., JOVANOVIC, P., STEVANOVIC (2016a): Variability of yield and chemical composition in soybean genotypes grown under different agroecological conditions of Serbia. Romanian Agricultural Research, *33*: 29-39.

POPOVIĆ, V., D., TERZIĆ, G., DRAŽIĆ, M., ČUROVIĆ, M., JOVANOVIĆ, V., RAJIČIĆ, J., IKANOVIĆ, D., ĐOKIĆ (2016b): Production *Glycine max* in double cropping in order to provide high productivity quality biomass and soil conservation. Proceedings in Conference "Innovative Models of Ecosystem Engineering". Belgrade, (in Serbian): 36-47.

POSADAS, L. (2017): Recurrent selection for increased seed yield in two soybean populations with distinct genetic backgrounds. Dissertation. Faculty of the Graduate College at the University of Nebraska. Lincoln, Nebraska July, 2013.

QUATARA, S., D.B., WEAVER (1994): Effect of growth habit on yield and agronomic characteristics of late-planted soybean. Crop Sci., *34* (4): 870-873.

SADEGHIPOUR, O., S., ABBASI (2012): Soybean response to drought and seed inoculation. World Applied Sciences Journal, *17*(1): 55-60.

STOJKOVIĆ, S., N., DELETIĆ, M., BIBERDŽIĆ, D., BEKOVIĆ, M., AKSIĆ (2008): Varijabilnost i povezanost komponenti prinosa kod S1 i HS potomstava jedne F3 poulacije kukuruza. Selekcija i semenarstvo, *XIV*(1-4): 63-68.

SUDARIĆ, A., M., VRATARIĆ, T., DUVNJAK (2002): Quantitative analysis of yield components and grain yield for soybean cultivars. Poljoprivreda, *8*(2):11-15.

TINIUS, C.N., J.W., BURTON, T.E., CARTER JR. (1991): Recurrent selection for seed size in soybean: Response to selection in replicate populations. Crop Sci., *31*: 1137-1141.

VARNICA, I., S., PETROVIC, A., REBEKIC, S., GUBERA, K., JUKIC, G., JUKIC (2018): Characterization and interrelationships of soybean [*Glycine max* (L.)] Merrill] yield components during dry and humid seasons. Journal of Central European Agriculture, *19* (2): 466-481.

VELLO, N.A., F.M., NAZATO (2017): Recurrent Selection. In: Lopes da Silva, F., A., Borem, T., Sedyama, W., Ludke (eds) Soybean Breeding. Springer, Cham., 171-191.

SMANJENJE KOMPONENTI PRINOSA I MORFOLOŠKIH OSOBINA LINIJA SOJE U PUNOM SRODSTVU U USLOVIMA SUŠE

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Izvod

Soja, kao biljna vrsta, potiče iz regiona sa povoljnim uslovima vlage i temperature za njen rast i razviće. Sa širenjem areala gajenja soje, nastala je potreba za sortama sa većom tolerancijom i stabilnijim prinosima zrna u uslovima suše. U cilju stvaranja prinosnih sorti, za formiranje materijala u ovom radu, korišćena je metoda ukrštanja u punom srodstvu (FS) koja pripada metodama rekurentne selekcije. Osnovni princip ove grupe metoda su ukrštanja u ciklusima u cilju akumulacije poželjnih gena. Iz kombinacije ukrštanja sorti Kunitz i Kador, odabrane su tri najprinosnije $F_{2:3}$ linije, za dve FS kombinacije ukrštanja. Potomstva dve FS kombinacije ukrštanja su na dve lokacije u toku dve godine (2011 sa povoljnijim i 2012 sa manje povoljnim rasporedom padavina). Vrednosti prinosa zrna po biljci, najvažnijih komponenti prinosa i morfoloških osobina su se smanjile u manje povoljnim uslovima. Najviše se smanjio broj mahuna i broj zrna po biljci a najmanje masa 1000 zrna. Bez obzira na srodnost testiranog materijala, uočene su značajne razlike reakcije na sušu, kako između dva FS potomstva, tako i unutar potomstava svake kombinacije. Prinos zrna soje je kompleksna osobina pod jakim uticajem uslova spoljne sredine. U nepovoljnim uslovima kod potomstava dve sestrinske kombinacije ukrštanja, došlo je do smanjenja prinosa zrna po biljci od 26.5-36,0% i 25,6-42.7%, broja mahuna po biljci od 18.6-33.0% i 12.6-38.2%, broja zrna po biljci od 18.1-30,2% i 14.3-37.6%. Identifikovana su tri potomstva iz FS ukrštanja sa najmanjim smanjenjem prinosa pogodna kao početni materijal za stvaranje linija i sorti sa većom tolerancijom prema uslovima suše.

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