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Interdependence of yield and soybean yield components

Vojo Radić, Ilija Komljenović, Miloš Berić

University of Banja Luka, Faculty of Agriculture, Banja Luka, Bosnia and Herzegovina

Abstract

This paper presents the results of a two-year study of six selected soybean genotypes with the aim of examining which of the genotypes in the given production conditions give the best results in regards with the amount and quality of seed yield. All genotypes belong to a zero-maturity group. The correlation between the grain yield per plant and other studied traits was tested through linear (simple) correlations. The testing showed that the following traits had a positive highly significant impact on seed yield: the number of seeds per plant (0.917**), seed germination energy (0.897**), seed moisture content (0.803**), plant height (0.802**), seed germination (0.789**), the number of seeds in pods (0.696**), the number of harvested plants per m^{-2} (0.590**), the number of plants (phenophase 1-3 in the three-leaf stage) per m^2 (0.550**), 1000 seed mass (0.471**), and the height to the first node (0.412**).

Keywords: soybean, genotype, correlations, yield

Introduction

Soybean (*Glycine max L. Merr.)* is one of the leading oil and protein plants in the world today (FAOSTAT, 2016), recognized as a high quality source of human and animal feed, a significant source of healthy materials, and an important raw material for the processing industry (Vratarić and Sudarić, 2008). Soybean is one of the most important plant species cultivated today (Radić, 2019).

Yield and soybean yield components are quantitative traits, and their expression is heavily influenced by environmental conditions (Paul et al., 2003; Karasu et al., 2009; Popović et al., 2016; 2019; 2020; Milanović et al., 2020;

Ikanović et al., 2021). The number of pods, the number of grains, and the kernel weight are considered to be the most important components of soybean grain yield, including the number of pods and the number of grains per unit area (De Burin and Pedersen, 2009). Grain yield per plant and number of grains per plant are an effective criterion for soybean selection for increased grain yield (Sudarić et al., 2002).

Through a three-year study on 12 soybean genotypes, Ghodrati (2013) found a strong positive correlation between the seed yield and plant height. Increasing the height of the plant increases the number of nodules per plant, the number of pods per plant and the number of grains per pod and per plant, and protein yield.

Malik et al. (2009) investigate the relationship of agro-morphological traits on 92 soybean genotypes that are a potential new source of genetic variability of the breeding program in Pakistan. They presented that phenotypic selection could be carried out on the basis of morphological characteristics such as leaf area, plant height, the number of pods per plant, the number of branches per plant, and weight of 1000 grains, for which a highly significant and positive correlation with grain yield was found.

Soybean yield is the product of a number of components and their interactions that can affect yield directly or indirectly. Therefore, it is important to assess the contribution of each trait in order to make better use of those with greater impact (Malik et al., 2014). Kobraee and Shamsi (2011) conclude that the property of the number of grains per plant under stress conditions has the greatest direct impact on yield.

Srebrić (2021) studied the relationship between grain yield per plant and other studied traits between maternal offspring and corresponding nursing crosses.

The aim of this study is to determine which yield components have the greatest impact on soybean production. Determining the differences in individual parameters between genotypes as well as their interdependence are of great importance for the prediction of soybean yield.

Material and Methods

The experiment was conducted in two growing seasons at the Sitneši site (*N 45 ° 03'38 ", E 17 ° 33'56", 167 m* altitude). Six soybean zero genotypes (*G1, G2, G3, G4, G5, G6*) were used in the study. A random block system in four replicates was used to set up the experiment. The area of the experimental unit was 6 m^2 (2x3 m) with a row spacing of 0,5 m. The distance between the experimental units was 1 m.

During the vegetation, the following parameters were measured: the number of plants per m^2, the height to the first node, the height of the whole plant, the number of secondary branches, and the number of plants before harvest. The number of plants per unit area was determined by the square method. For the analysis of other parameters, 10 plants were taken from each experimental unit. A total of 480 plants were analysed (10 plants / experimental unit x 6 genotypes x 4 replicates x 2 years). Before harvest, the number of plants per m^2 was counted. After harvest, the following parameters were analysed: the number of seeds in a pod, the number of seeds per plant, the mass of 1000 seed g, germination energy, seed germination, the mass of one thousand seeds, and seed yield.

The measurement results were statistically processed using the Statistical Package for Social Sciences program (19). The GLM procedure was used for the analysis of variance (ANOVA). The *Duncan's Multiple Range Tes*t (DMRT) was used to determine the significance of differences between genotypes and their ranking for significance levels $P = 0.01$. Correlative relationships between the studied properties were calculated as the Pearson correlation coefficients, and the significance of the relationships was determined.

Results and Discussion

For successful selection of high-yielding genotypes, one needs to know the connection between the yield components and seed yield itself, as well as the relationship between the yield components and changes in individual components under the influence of environmental factors. Different genotypes exert different influence of individual yield parameters on yield. Table 1. shows the mean values of the parameters analysed in six soybean genotypes in a two-year period.

The analysis of variance by F-test statistics revealed that there was a highly significant difference between the analysed genotypes as well as between years. A post-hock Duncan test was used to determine which genotypes were highly significant. The largest difference was found in grain yield and the number of plants per unit area, and the smallest number was found in the grains in pods and seed germination. The number of plants per unit area had a significant impact on seed production. Taking into account morphological characteristics, the number of seeds per plant had the greatest influence on seed production.

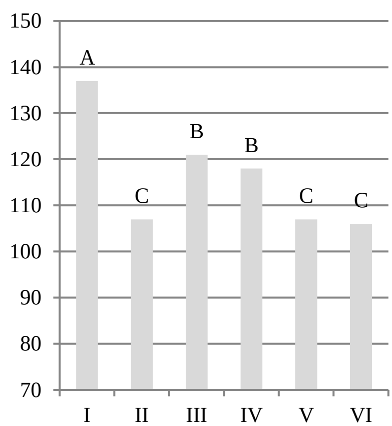
De Burin and Pedersen (2009) came to similar results in their research. Qualitative properties such as the mass of a thousand seeds, germination energy and germination by the Duncan’s test were classified into a smaller number of intervals. These traits had less variability compared to the test genotypes.

Tab. 1. Mean values of yield and yield components of the tested soybean genotypes

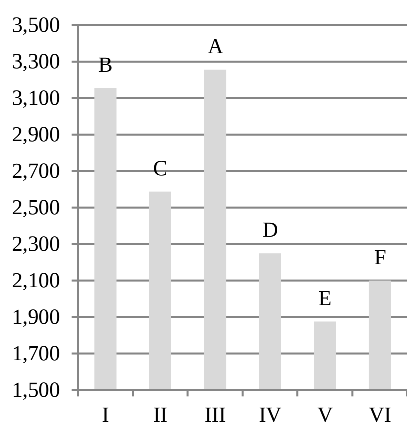
Genotype	I	II	III	IV	V	VI	x̄
No. plants per *m*$^{-2}$	49.9^{B}	50.5^{B}	51.5^{A}	43.9^{C}	40.9^{D}	44.8^{C}	46.9
High plants *cm*	74.4^{C}	70.5^{D}	85.5^{A}	74.6^{C}	77.8^{B}	78.1^{B}	76.8
High to first node *cm*	18.8^{B}	19.1^{B}	24.4^{A}	16.0^{C}	23.6^{A}	19.6^{B}	20.3
No. secondary branch	3.5^{B}	4.6^{A}	3.6^{B}	5.0^{A}	3.3^{B}	2.9^{B}	3.8
No. plants in harvest time per *m*$^{-2}$	47.0^{B}	47.8^{B}	49.6^{A}	42.1^{C}	39.8^{D}	42.8^{C}	44.9
No. seeds per plants	137^{A}	107^{C}	121^{B}	118^{B}	107^{C}	106^{C}	116
No. seeds per pod	2.2^{A}	2.3^{A}	2.3^{A}	2.3^{A}	2.2^{A}	2.2^{A}	2.2
Energy of seed germination	85^{A}	82^{BC}	85^{A}	83^{B}	82^{BC}	81^{C}	83
Seed germination	89^{A}	87^{AB}	87^{AB}	85^{B}	87^{B}	86^{B}	87
Kernel weight in *g*	119^{C}	160^{A}	128^{B}	122^{C}	122^{C}	120^{C}	129
Moisture	11.64^{AB}	11.71^{A}	11.61^{AB}	11.36^{AB}	11.63^{AB}	11.33^{B}	11.55
Grain yield *kg ha*$^{-1}$	3.154^{B}	2.588^{C}	3.256^{A}	2.250^{D}	1.875^{E}	2.100^{F}	2.537

*A, B, C... *Values denoted by the same letter are not significantly different at the p=0.01 level of probability (the Duncan's Multiple Range Test).*

Graph 1. shows the mean values of the number of seeds per plant for each tested genotype. Based on the Duncan's test classification, it can be seen that there are three highly significant groups that differ from each other. Genotype I differs significantly in the number of seeds per plant compared to all other genotypes. Genotypes II, IV, and V are classified in interval C and there is no statistically significant difference between them. Graph 2. shows that there is a high significant difference in yield between all six genotypes. The highest yield was achieved in genotypes III and I, and the lowest in genotypes V and VI. The distribution of the mean intervals based on the Duncan's test shows a similar trend in the number of seeds per plant and yield. Based on these values, we come to the conclusion that there is high influence of the number of seeds per plant on the yield.



Graph 1. Number of seeds per plant



Graph 2. Grain Yield (kg ha^{-1})

The Pearson's correlation coefficient was used as a parameter to determine the correlation of individual examined properties. The correlations were calculated based on 480 analysed plants, as shown in Table 2.

A completely positive correlation has been found between the number of plants after emergence and the number of plants in harvest. Very strong positive correlations have been found between the plant height at technological maturity with the following parameters: the number of seeds in the pod (0.766**) or the number of seeds per plant (0.820**), and seed yield (0.802**).

Popović et al. (2020) found in their research that there was a positive significant correlation between the plant height and 1000 seed mass (r = 0.83). Auki et al. (2011) found that there was a moderate positive correlation between the seed yield and germination (r = 0.660**). Basić et al. (2006) as well as Berić (2020) state that there are strong positive correlations between the number of pods per plant and the number of seeds per plant, and the number of floors per plant and the mass of seeds per plant. A high degree of interdependence was found between the seed yield per plant and the qualitative characteristics of germination energy (0.897**) and germination (0.789**). Đukic et al. (2011) observed a moderate positive correlation between the seed yield and germination in their research.

The number of seeds per plant has shown a medium degree of interdependence with the number of secondary branches (0.453**) and the mass of 1000 seeds (0.481**). The mass of 1000 seeds has shown a very high degree of interdependence with most of the analysed parameters, and high ($p < 0.05$) with the plant height (0.348 *) and number of seeds per plant (0.345*). This is a property that directly affects the yield, because it represents one of the three basic components of yield (Đukić et al., 2009). No negative correlation has been observed for the number of seeds per plant and the height to the first floor of the pod (-0.045) as well as for the height to the first floor of the pod and the weight of 1,000 seeds (0.057).

Tab. 2. Coefficients of correlation for the tested soybean traits

		1	2	3	4	5	6	7	8	9	10	11
2	r	.102										
	p	.488										
3	r	.052	.228									
	p	.726	.119									
4	r	.139	.305*	-.252								
	p	.345	.035	.084								
5	r	.953**	.169	.092	.211							
	p	.000	.250	.533	.150							
6	r	.253	.820**	-.045	.453**	.311*						
	p	.083	.000	.759	.001	.031						
7	r	.108	.766**	.005	.369**	.164	.764**					
	p	.465	.000	.973	0.010	.267	.000					
8	r	.247	.835**	.090	.412**	.290*	.926**	.735**				
	p	.091	.000	.543	.004	.0450	.000	.000				
9	r	.218	.720**	.064	.266	.219	.788**	.646**	.777**			
	p	.137	.000	.667	.067	.135	.000	.000	.000			
10	r	.379**	.348*	-.057	.453**	.415**	.345*	.481**	.400**	.416**		
	p	.008	.015	.702	.001	.003	.016	.001	.005	.003		
11	r	.220	.790**	.132	.493**	.302*	.860**	.750**	.826**	.697**	.550**	
	p	.134	.000	.371	.000	.037	.000	.000	.000	.000	.000	
12	r	.550**	.802**	.080	.412**	.590**	.917**	.696**	.897**	.789**	.471**	.803**
	p	.000	.000	.588	.004	.000	.000	.000	.000	.000	.001	.000

*- *.** Significant at p <0.05. p <0.01; the Pearson Correlation Coefficients. N=48.*
- 1 Number of plants per m^2; 2 Plant height; 3 Number of secondary branches; 4 Height to the first node; 5 Number of harvested plants per m^2; 6 Number of seeds per plant; 7 Number of seeds per pod; 8 Germination seed energy; 9 Seed germination; 10 1000 seed mass; 11 Seed moisture; 12 Seed yield

Conclusion

Based on the research results and their analysis, the following conclusions can be drawn:

Seed yield and soybean yield components in the six genotypes examined have shown a high degree of divergence in the Duncan's post-hock test. The largest number of intervals has been found in the number of plants per unit area in the harvest, plant height, and the number of seeds per plant. The number of seeds per pod, the number of secondary branches, and the germination of seeds had less variability.

Highly significant correlations have been found between the seed yield and yield components. A very high degree of interdependence of yield has been determined for the number of seeds per plant (0.917 **), seed germination energy (0. 897**), and plant height (0.802**).

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Међузависност приноса и компоненти приноса соје

Војо Радић, Илија Комљеновић, Милош Берић

Универзитет у Бањој Луци, Пољопривредни факултет, Бања Лука, Босна и Херцеговина

Сажетак

У овом раду су приказани резултати двогодишњег испитивања шест одабраних генотипова соје са циљем да се испита који од генотипова у датим условима производње даје најбоље резултате у висини и квалитету приноса сјемена. Сви генотипови припадају нултој групи зрења. Повезаност приноса зрна по биљци и осталих проучаваних особина, тестирана је преко линеарних (простих) корелација. Тестирањем је утврђено да су позитивни високо значајни утицај на принос сјемена имали: број сјемена по биљци (0,917**), енергија клијања сјемена (0,897**), садржај влаге у сјемену (0,803**), висина биљака (0,802**), клијавост сјемена (0,789**), број сјемена у махуни (0,696**), број биљака у жетви по m^2 (0,590**), број биљака (фенофаза 1-3 тролиске) по m^2 (0,550**), маса 1.000 сјемена (0,471**), висина до прве етаже (0, 412**).

Кључне ријечи: соја, генотип, корелације, принос.

Corresponding author: Vojo Radić
E–mail: vojo.radic@agro.unibl.org

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