Sjemenarstvo 21(2004)3-4 UDK: 633.34;631.559.2;631.52(045)=020
Izvorni znanstveni rad

GENETIC ADVANCE IN YIELD COMPONENTS, GRAIN YIELD AND GRAIN QUALITY OF SOYBEAN OS-LINES

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SUMMARY

Genetic improvement of soybean cultivars has had significant role in yield increasing as well as in development, improvement and stabilization of soybean production, respectively. The aim of this study was to evaluate genetic advance in yield components, grain yield and grain quality of soybean throughout analysis of agronomic values of new domestic elite breeding soybean lines in comparison with commercial cultivars. The reliability of the grain quantity traits as selection criteria in soybean breeding on grain yield were determined, too. The investigations were carried out at the Agricultural Institute Osijek from 2001 to 2003 and involved 31 domestic soybean genotypes ranging maturity groups I. Mean values, broad-sense heritability, genetic gain and relative genetic gain from selection were calculated for grain yield components, grain yield, protein and oil content in grain. The obtained results of quantitative genetic analysis indicated progress through breeding in grain quantity and quality traits that will contribute to further improving and increasing of soybean production in our region. Likewise, recent breeding materials represent good genetic basis for future hybridizations aimed at advancing of quantity and quality of grain yield in soybean genetically. Regarding to traits reliability as selection criteria, grain yield components are determined as more reliable criteria for selection of superior genotypes than grain yield *per se* due to higher heritability (61.87-82.31%) and better progress in selection (10.63-22.78%). Grain quality traits had medium heritability (60.04-65.89%) and better progress in selection (6.95-8.94%) compared to grain yield that had less heritability (29.87%) and relative genetic gain from selection was 0.43%.

Keywords: soybean (*Glycine max* (L.) Merrill), grain yield, grain quality, yield components, genetic advance, heritability, genetic gain from selection, relative genetic gain.

INTRODUCTION

Genetic improvement of soybean (*Glycine max* (L.) Merrill) cultivars, as result of continual breeding and selection, has had significant role and great contribution in unitary yield increasing and throughout it on development, improvement and stabilization of soybean production, respectively. Although, yield increasing is significantly through genetic manipulation of soybean, this increase cannot be attributed to only improved cultivars, because advances in cultural practices and general management have also played a significant role in yield increasing (Fehr, 1983; Specht et al.,1999).

The amount of soybean yield increasing due to breeding (genetic progress) was the objective of many studies. Luedders (1977) tested 21 first- and second cycle soybean cultivars to estimate genetic improvement. It was estimated that the increase in yield for the first and second cycles was 26 and 16%, respectively. Specht and Williams (1984) observed an average rate of yield improvement of 18.8 kg ha^{-1} yr^{-1} from 1902 to 1977 for maturity group 00 to IV. However, when they summarized only cultivars from hybridization after 1939, the average annual gain was 12 kg ha^{-1}. Karmakar and Bhatnagar (1996) compared cultivars developed from 1969 to 1993 in India. They found that annual genetic gain was 22 kg ha^{-1}. Voldeng et al (1997) tested cultivars from maturity groups 000-0 that released between 1934 and 1992 in Canada. They found an annual yield increase of 9.3 kg ha^{-1} yr^{-1} (0.5%) until 1976, and after 1976 it was 13 kg $ha^{-1}yr^{-1}$ (0.7%). Recent estimates indicate soybean yields are improving at a rate of about 23 kg $ha^{-1}yr^{-1}$ (Specht et al., 1999) and 14 kg $ha^{-1}yr^{-1}$ (Ustun et al., 2001), respectively. Obviously is that the rate of genetic improvement may have declined since the time that cultivar development by hybridization begun. Luedders (1977) and Specht and Williams (1984) noted that the first cycle of cultivar development by hybridization provided a larger percentage yield increase than subsequent cycles. The lower rate may reflect the difficulty in obtaining genetic improvement beyond that of cultivars that are already well adapted. It also may be associated with the limited amount of genetic diversity among the high-yielding cultivars used as parents for hybridization. Essentially, all of the genetic gains in soybean yield have been achieved by traditional breeding methods, involving hybridization and phenotypic selection (Coryell et al., 1999).

Genetic improvement in grain yield is based on the improvement of genetic basis of traits that determine its quantity and quality. Since these traits are of quantitative nature, the estimates of different selection parameters are very important both for the better understanding of the nature and magnitude of genetic variability present in the available breeding materials and for successful breeding process (Soldati, 1995; Vratarić and Sudarić, 2000). Among selection parameters, the heritability estimations have considerable importance due to provide information about the traits' inheritance as well as make possible to evaluate the trait reliability as selection criteria in soybean breeding. Thus, higher heritability estimations of trait are indicators of a greater portion of genetic (heritable) component in relation to the environmental and genotype x environment interaction (nonheritable) components in the phenotypic expression of a trait. It means that the expression of trait is less variable with the changes of environment and trait is more stable allowing for its use as an efficient select criterion in the breeding process (Burton, 1987; Hill et al., 1998). Likewise, the heritability estimations serve for the estimation of genetic gain from selection as well as to predict the selection progress, respectively. According to Simmonds (1979), the genetic gain is determined by the variability of reference population, trait heritability and selection intensity. The higher genetic gain from selection results from higher phenotypic variability, higher heritability of selected traits and higher selection intensity. Finally, the success of selection is measured by the increased grain yield and by the achieved genetic improvement, respectively. Therefore, the quantitative genetic analyses and statistical techniques are used to determine the relative importance of yield components in the overall yield formation process. Results of such analyses significantly contribute to formulating an effective selection program for improvement grain yield (Burton, 1987). Moreover, the results of quantitative genetic analysis depend of set of tested materials and set of environmental conditions of investigations. Hence, any comments of results of quantitative analysis could be limited on tested materials and conditions were selection has been done.

The objective of this study was to evaluate genetic advance in yield components, grain yield and grain quality of soybean throughout analysis of agronomic values of new domestic elite breeding lines in comparison with commercial cultivars. Furthermore, on the basis of the obtained heritability estimations and relative genetic gain from selection for the traits that determinate the quantity of soybean grain, should be able to evaluate their reliability as selection criteria in soybean breeding on grain yield.

MATERIAL AND METHODS

This research was set up at the experimental field of the Agricultural Institute Osijek (Eastern Croatia) from 2001 to 2003 year. The experimental material involved 31 soybean genotypes: 3 commercial cultivars (standards) and 28 elite breeding lines. Tested elite breeding lines have developed from different hybridizations within the Institute's soybean breeding program and derived from previously cycle of selection on the basis of their performances. Standards are released cultivars of the Institute that have grown in commercial production in Croatia. According to the length of vegetation period, they belong to maturity group I. Field trials were designed as a randomized complete block (RCBD) in four replications on basic plot of 10 m^2. The experimental plots were sown by precise planting machine in optimal time for soybean. Currently accepted levels of management and cultural practices for soybean were applied each year in trial. At maturity, 30 plants per plot were randomly selected, i.e. the sample of each genotype per experimental year amounted 120 plants. Plots were harvested with a small plot harvest combine, when genotypes reached the full harvest maturity. After harvesting, grain yield from each plot was weighed and converted into t/ha on standard of 13% seed moisture content. In laboratory, the following traits were determined: plant height (cm), number of fertile nodes per plant, pods number per plant, seeds number per plant, seed yield per plant (g), above-ground mature plant weight (g). Harvest index per plant (%) was calculated from the ratio of seed yield per plant to above-ground mature plant weight. 1000 seed weight (g) and grain quality traits: protein and oil content in grain (% in absolutely dry matter of grain-ADM) were determined from the average sample of grain for each genotype. Protein and oil content in grain were determined by Infratec 1241 Analyzer.

The summarized experimental data for yield components, grain yield and grain quality traits were subjected with analysis of variance and the means were tested using an Least Significant Difference (LSD) test at $P \leq 0.05$ and $P \leq 0.01$. Broad-sense heritability, denoted by H^2, refers to the amount of genetic variance expressed as a proportion of the total phenotypic variance (%). It was calculated according to the method suggested by Singh et al. (1993). The genetic gain from selection was estimated after the method by Allard (1960). Relative genetic gain from selection (%) represents a relationship between the genetic gain from selection and mean value of the trait.

The soil type at the experimental site was classified as an eutric cambisol. The chemical soil properties were: pH 7.00 in H_2O; humus 1.83%; 26.3 mg P_2O_5/100 g of soil and 25.2 mg K_2O/100 g of soil. Meteorological data (monthly mean air temperature and monthly total precipitation) for the investigated period (2001-2003) over soybean growing season at location Osijek are presented in Table 1.

Table 1. Monthly mean air temperatures (°C) and monthly total precipitation (mm) per years during soybean growing seasons, 2001-2003, Osijek

Tablica 1. Srednja mjesečna temperatura zraka (°C) i mjesečna količina oborina (mm) po godinama tijekom vegetacije soje, 2001.-2003., Osijek

Month Mjesec	Air temperature (°C) Temperatura zraka			Precipitation (mm) Oborine		
	2001	2002	2003	2001	2002	2003
April - Travanj	10.8	11.5	11.5	71.5	57.6	9.1
May - Svibanj	18.4	19.1	20.5	59.5	155.8	43.2
June - Lipanj	18.1	22.1	24.7	238.9	21.5	25.3
July - Srpanj	21.8	23.0	22.9	77.1	84.6	70.3
August - Kolovoz	22.7	21.3	24.6	7.1	54.7	23.4
September - Rujan	14.9	16.0	16.7	195.2	74.8	49.3
October - Listopad	13.9	11.6	9.7	5.1	58.1	145.4
Total - Ukupno				654.4	507.1	366.0

RESULTS AND DISCUSSION

The average values range and mean values of grain yield components, grain yield, protein and oil content in grain for tested cultivars and lines (genotypes) over three-years period with results of statistical analysis are presented in Table 2.

Table 2. The average values range and mean values of analysed traits in soybean, 2001-2003, Osijek

Tablica 2. Raspon prosječnih vrijenosti i srednje vrijednosti analiziranih svojstava soje, 2001-2003, Osijek

Traits Svojstva	Cultivars - Kultivari		Lines - Linije		LSD	
	Range Raspon	$\bar{x}$	Range Raspon	$\bar{x}$	0.05	0.01
Plant height (cm) Visina biljke	94.2-112.8	101.1	91.4-108.0	98.7	3.45	4.14
Num. of fertile nodes plant^{-1} Broj plodnih etaža/biljci	12.4-15.6	13.9	15.4-17.8	16.3	2.02	2.63
Pods number plant^{-1} Broj mahuna/biljci	27.1-38.4	34.6	32.5-41.4	38.9	3.24	4.05
Seeds number plant^{-1} Broj zrna/biljci	80.1-110.7	87.3	89.4-107.4	95.6	4.62	5.03
Seed yield plant^{-1} (g) Masa zrna/biljci	11.3-14.9	12.7	13.6-18.2	15.4	1.46	2.06
Harvest index plant^{-1} (%) Žetveni indeks/biljci	36.8-42.7	39.1	41.5-47.6	44.5	2.67	3.44
1000 seeds weight (g) Masa 1000 zrna	132.4-166.4	154.2	151.3-180.0	162.6	4.25	6.61
Grain yield (t/ha) Urod zrna	3.4-4.6	3.8	3.7-4.8	4.4	0.14	0.51
Protein content in grain (%) Sadržaj bjelančevina u zrnu	36.1-39.8	37.4	37.1-40.1	38.6	0.43	0.91
Oil content in grain (%) Sadržaj ulja u zrnu	18.4-21.2	19.3	19.4-22.0	21.2	0.96	1.48

The results have showed board values range for all analysed traits at tested genotypes. The differences among genotypes in the average values of grain yield components, grain yield, protein and oil content in grain were statistical significant, suggesting a level of genetic diversity among the tested materials. At the overall average, tested lines had statistical significant ($P \leq 0.01$) higher values of majority yield components: pods number plant^{-1}, seeds number plant^{-1}, seed yield plant^{-1}, harvest index plant^{-1}, 1000 seeds weight, as well as grain yield, protein and oil content in grain in relation to the tested cultivars, while at level of $P \leq 0.05$, lines had a larger number of fertile nodes plant^{-1} than cultivars. Tested cultivars had higher mean values of plant height in comparison with tested lines, but without statistical significance.

As a whole, the summarized and analyzed data for level of grain yield components, grain yield and grain quality traits indicated considerably higher agronomic values of the new breeding materials (lines) compared with agronomic values of the standard materials (cultivars). It suggests on certain progress in soybean breeding program at the Institute on traits that determine quantity and quality of soybean grain. Respectively, these results are indicator of the genetic improvement of cultivars that will contribute to the further improving and increasing of soybean production in our region. Also, by the breeding aspect, recent breeding materials represent good genetic background for future hybridizations aimed at advancing of quantity and quality of grain yield in soybean genetically.

The results of the components of phenotypic variance analysis for the traits studied (Table 3) showed that the genetic variance (heritable component) has a larger portion in relation to the environmental variance and variance of interaction genotype x environment (nonheritable components) in the phenotypic expression of all analyzed grain yield components as well as grain quality characteristics, whereas at the phenotypic expression of grain yield, nonheritable components have a larger part than the heritable component.

The differences in the portion of genetic variance in the total phenotypic variance among analyzed traits resulted in differences in broad-sense heritability of traits (Table 3). The traits with very high heritability were: seeds number plant^{-1} (82.31%), and seed yield plant^{-1} (81.17%). High heritability was obtained for 1000 seeds weight (77.19%), plant height (77.13%), pods number plant^{-1} (74.80%) and number of fertile nodes plant^{-1} (73.11%). Medium heritability was for protein content in grain (65.89%), harvest index plant^{-1} (61.87%), and oil content in grain (60.04%). Grain yield had low heritability (29.87%), what means that about 70% of the observable variance in soybean yield is due to nongenetic effects. Since the phenotypic expression of yield components is amount of heritable variation and less on nonheritable, yield components are appear to be more reliable as selection criteria than grain yield *per se*. Hence, the selection on higher grain yield should be done in early inbreeding generations indirectly, over grain yield components, while in later inbreeding generations (F_5, F_6), selection on higher grain yield could be done directly (per se). These findings correspond well with those reported elsewhere for soybean (Konieczny et al, 1994; Taware et al, 1997; Sudarić et al 1997, 2002; Vratarić et al, 1998, 1999).

Tablica 3. Komponente fenotipske varijance i procjene heritabilnosti u širem smislu (H2) za analizirana svojstva soje, 2001.-2003., Osijek

Table 3. Components of phenotypic variance and the estimations of broad-sense heritability (H^2) for analysed traits in soybean, 2001-2003, Osijek

Traits Svojstva	Variance Varijance				H^2 (%)
	Phenotypic Fenotipska V_P	Genetic Genetska V_G	Environmental Okolinska V_E	Interaction Interakcija V_I	
Plant height (cm) Visina biljke	61.2540	47.2465	8.2214	5.7861	77.13
Num. of fertile nodes plant^{-1} Broj plodnih etaža/biljci	1.9681	1.4389	0.3670	0.16223	73.11
Pods number plant^{-1} Broj mahuna /biljci	22.8035	17.0562	3.6319	2.1154	74.80
Seeds number plant^{-1} Broj zrna/biljci	132.6195	109.1652	16.3358	7.1185	82.31
Seed yield plant^{-1} (g) Masa zrna/biljci	5.0119	4.0683	0.6211	0.3225	81.17
Harvest index plant $^{-1}$ (%) Žetveni indeks/biljci	27.3852	16.9433	6.9658	3.4761	61.87
1000 seeds weight (g) Masa 1000 zrna	403.7604	311.6723	48.3655	43.7226	77.19
Grain yield (t/ha) Urod zrna	1100.06	328.5744	260.4439	511.0417	29.87
Protein content in grain (%) Sadržaj bjelančevina u zrnu	5.1958	3.4236	1.0745	0.6977	65.89
Oil content in grain (%) Sadržaj ulja u zrnu	2.9252	1.7562	1.1005	0.0685	60.04

The obtained estimations of genetic gain and relative genetic gain from selection for the analyzed traits are shown in Table 4.

Regarding to the grain yield components, the highest relative genetic gain from selection was recorded for seed yield plant^{-1} (22.78%), while the lowest was recorded for the plant height (10.63%). The relative genetic gain for grain yield amounts 0.43%, for protein content 6.95% and for oil content 8.94%, respectively. According to these results, the genetic gain from selection was higher for grain yield components than the genetic gain for grain yield and grain quality traits that is resulted from differences in heritability among analysed traits. Similar findings have been reported by Spech and Williams (1984), Voldeng et al. (1997), Sudarić et al. (1997, 2002), Vratarić et al. (1998, 1999), Ustun et al (2001).

Table 4. The mean values, genetic gain and relative genetic gain from selection for analyzed traits in soybean, 2001-2003, Osijek

Tablica 4. Srednje vrijednosti, genetska dobit i relativna genetska dobit od selekcije za analizirana svojstva soje, 2001.-2003., Osijek

Traits Svojstva	Mean value Prosjek	Genetic gain Genetska dobit	Relative genetic gain (%) Relativna genetska dobit
Plant height (cm) Visina biljke	99.9	10.62	10.63
Num. of fertile nodes plant^{-1} Broj plodnih etaža/biljci	15.10	1.81	11.99
Pods number plant^{-1} Broj mahuna /biljci	36.75	6.29	17.12
Seeds number plant^{-1} Broj zrna/biljci	91.45	16.68	18.24
Seed yield plant^{-1} (g) Masa zrna/biljci	14.05	3.20	22.78
Harvest index plant $^{-1}$ (%) Žetveni indeks/biljci	41.80	5.79	13.85
1000 seeds weight (g) Masa 1000 zrna	158.40	27.30	17.23
Grain yield (kg/ha) Urod zrna	4.100	17.44	0.43
Protein content in grain (%) Sadržaj bjelančevina u zrnu	38.00	2.64	6.95
Oil content in grain (%) Sadržaj ulja u zrnu	20.25	1.81	8.94

On the basis of estimations of heritability and relative genetic gain from selection obtained in this study, grain yield components, particularly seeds number per plant and seed yield per plant are determined as more reliable criteria for selection of superior genotypes than grain yield *per se,* due to higher heritability and better progress in selection. In general, these results may assist breeders in selecting appropriate traits as selection criteria for improving the grain yield in soybean breeding populations.

GENETSKI NAPREDAK U KOMPONENTAMA URODA, URODU ZRNA I KAKVOĆI ZRNA OS-LINIJA SOJE

SAŽETAK

Genetski napredak kultivara soje ima značajnu ulogu u povećanju uroda zrna, a kroz to, na razvoj, unaprijeđenje i stabilizaciju proizvodnje soje. Cilj ovog istraživanja bio je procijeniti genetski napredak u komponentama uroda, urodu zrna i kakvoći zrna soje analizom agronomske vrijednosti novih domaćih elitnih linija soja u usporedbi sa komercijalnim kultivarima. Pouzdanost svojstava kvantitete zrna kao selekcijskih mjerila u oplemenjivanju soje na urod zrna također je određivana. Pokusi su provedeni na pokusnom polju Poljoprivrednog instituta Osijek u razdoblju od 2001 do 2003. Ispitivanja su obuhvaćala 31 domaći genotip soje u okviru I. grupe zriobe. Prosječne vrijednosti, heritabilnost u širem smislu, genetska dobit i relativna genetska dobit od selekcije su izračunavani za komponente uroda, urod zrna, te sadržaj bjelančevina i ulja u zrnu. Dobiveni rezultati kvantitativno genetskih analiza ukazali su na postignuti napredak u oplemenjivanju soje na svojstva kvantitete i kakvoće zrna što će pridonijeti daljnjem unaprijeđenju i povećanju proizvodnje soje u našem području. Također, noviji oplemenjivački materijal predstavlja dobru genetsku osnovu budućih križanja usmjerenih na poboljšanje količine i kakvoće zrna soje. U pogledu pouzdanosti svojstava kao selekcijskih mjerila, komponente uroda zrna su određene kao pouzdanija mjerila u selekciji superiornih genotipova od uroda zrna *per se* zbog veće heritabilnosti (61.87-82.31%) i boljeg napretka u selekciji (10.63-22.78%). Svojstva kakvoće zrna imala su srednju heritabilnost (60.04-65.89%) i bolji napredak u selekciji (6.95-8.94%) u usporedbi s urodom zrna koji je imao nižu heritabilnost (29.87%), a relativna genetska dobit od selekcije iznosila je 0.43%.

Ključne riječi: soja (Glycine max (L.) Merrill), urod zrna, kakvoća zrna, komponente uroda, genetski napredak, heritabilnost, genetska dobit od selekcije, relativna genetska dobit.

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Primljeno - Received:
04. 09. 2004.