VARIABILITY OF YIELD COMPONENTS AND GRAIN QUALITY IN SEVERAL POPULATIONS OF SOYBEAN (*Glycine max* (L.) Merrill)

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ABSTRACT

High grain quality such as protein and/or oil contents are important characters for soybean grain when it is utilized for food requirement. In this study, we intent to determine variation of yield components and grain protein and oil content on several soybean populations. Nine populations of soybean were obtained from crosses between three lines as male and three varieties as female parents. The F1 grain and F2 grain obtained from each population were then planted by using randomize block design in 2014 and 2015 in a randomized block design. Days to harvest, grain weight plant^{-1}, 100-grain weight, grain yield m^{-2}, grain protein and oil content were measured from each entry. Genotypic variation and heritability were estimated in both generations. We observed significant ($p \leq 0.05$) genotypic variation among populations on grain weight plant^{-1}, 100-grain weight, grain yield m^{-2}, protein content, and oil content in F1 and F2 generations. Genotypic variance of days to harvest, grain weight per plant and 100-grain weight was greater in the F_1 than F_2 generation. On the other hand, genetic variance for grain yield, oil content and protein content was greater in the F_2 than the F_1 generation. Heritability ranged from 0.27 for grain protein content to 0.67 for 100-grain weight in F1 generation and from 0.22 for grain yield to 0.56 for 100-grain weight in F2 generation. Grain weight per plant was positively correlated to 100-grain weight but negatively correlated to grain protein content. Grain yield m^{-2} were positively correlated to 100-grain weight but negatively correlated to grain protein content, which leads to conclude that raising grain protein content may result the reduction of grain yield of a genotype.

Keywords: genotypic variance, heritability, oil content, protein content

INTRODUCTION

Protein and oil contents of the grain are very crucial traits and important economic determinant for soybean where it is utilized for human diet. Annually, there is more than 70% of national demand which is equals to 1.7 million tons of soybean grain has been imported to Indonesia. So that it is important here to increase yield as well as to improve grain quality such as protein and oil concentration through soybean breeding program.

Since early 2000, the breeding program has concentrated to study several traits correspond to chemical composition in soybean grain, including factors that controls them. Early study reported that protein concentration in soybean seed was controlled by the genotype and also influenced by environmental condition (Panthee *et al.*, 2005, Rotundo & Westgate, 2009; Dukic *et al.*, 2010) as well as by cultural practices such as fertilizer application (Win *et al.*, 2010).

Furthermore, both protein and oil concentration in the grain were also influenced by genetic environment interaction (Ning *et al.*, 2003; Sogut, 2006; Kang, 1998; Kumar *et al.*, 2006). Recent study confirmed that protein and oil contents as well as related traits were controlled significantly by additive and dominance components of variance (Rasyad *et al.*, 2016)

Considerable variation in grain protein and oil contents has been documented in several populations of soybean. documented variation of Grain protein content ranging from 34% to more than 40% mg g^{-1} and oil content from 150 to 220 mg g^{-1} have been reported on several populations in Turkey (Arioglu, 2007; Arslanoglu *et al.*, 2011). Wider variability both protein and oil content had been reported by Piper and Boote (1999) and Vollman *et al.* (2000) in which they found oil content ranging from 120 to 230 and protein from 255 to 589 mg g^{-1}.

Later studies has reported that an increase in grain protein content was followed by a decrease in grain yield and oil content in soybean (Li & Burton, 2002; Piper & Boote, 1999; Gunasekera *et al.*, 2006), reflecting the existence of negative correlation between both traits. The weight of 100 seeds of a soybean population was positively correlated to protein content but negatively correlated to grain yield (Rasyad *et al.*, 2016). In this study we intend to determine the genotypic variation and heritability of grain protein, grain oil content and their related traits in defined populations.

MATERIALS AND METHODS

Three varieties and three breeding lines with a wide variation of protein and oil contents were randomly chosen from fourteen varieties and five breeding lines as a reference population. The female genotypes assigned as males were mated to three females to produce nine F1 crosses. Crosses were carried out in a greenhouse in 2014 to produce enough F1 seed for progeny evaluation. Seed harvested from each F1 plants was then bulked to provide enough seed for F2 generation evaluation.

Two successive experiments were conducted at the University of Riau Agriculture experiment Station in Pekanbaru, Indonesia in 2014 and in 2015. The F1 seed used in the experiments were planted on 10 August 2014 and the F2 seed was grown on 18 April 2015. Soil type in the experiment station was *Inceptisol* (*fluventic dy*strudepts) characterized by low nitrogen and phosphorous contents.

Experiment 1. F1 Generation Evaluation

Fifteen F1 seeds obtained from each cross between three males and three females were planted in single-row plot with planting space of 20 cm within a row. The design used was a randomized complete block with three replications. The plant material were fertilized at planting date at a rate of 25 kg N, 25 kg P_2O_5, and 40 kg K_2O ha^{-1}, respectively.

Traits observed were days to harvest (DTH), grain weight per plant (GWP), 100- grain weight HGW), grain yield from each row-plot. Grain yield per row was then converted into yield m^{-2}. Crude protein and oil contents were obtained by sampled 15 g of grain from each row plot, and then dried to a moisture content of 130 mg g^{-1}. The grain was ground to a fine powder by a grain grinder then placed in a plastic jar until extraction. Oil was extracted with petroleum ether (40 – 60 ^{0}C) in soxhlet apparatus for 12 hours. Resulted solution then was dried with anhydrous sodium sulphate then removed by vacuum distillation at 30 ^{0}C. Grain oil percentage (GOC) was determined by calculating the weight differences as described by Maestri et al. (1998). Grain protein content (GPC) was determined by converting nitrogen concentration obtained by macro-Kjeldahl methods as described by AOAC (1980).

Experiment 2. F2 Generation Evaluation

The F2 seeds collected from each F1 plant population was bulked and planted in four-row plot at a rate of 13 plants m^{-2}. A randomized complete block design was used to evaluate the materials and four replications were made for each entry. Fertilizers rate were applied as previously described in experiment 1. Days to harvest, grain weight $plant^{-1}$, 100-grain weight, grain yield, protein and oil contents were observed at harvest from each entry. The procedure to measure the traits was as previously described in the Experiment 1.

Statistical Analysis

An analysis of variance was performed for each experiment with the model: $Y_{ijk} = \mu + r_i + p_j + e_{ijk}$, in which Y_{ijk} = phenotypic value of individual population *i;* μ = the overall mean; r_i = replication effect; p_j = the effect of populations *j. j* = 1-9; and e_{ijk} = the experimental error due to individual observation. Estimation of genotypic variance was achieved by translating covariance among population into genetic variance. The method used in translation of design components into causal genetic components followed the procedure of Hallauer *et al.* (2010). The among population variance component was expressed as the covariance of full sibs and further translated into genotypic variance.

Genetic correlation was calculated by dividing the covariance component by the square root of the product of the variance component of the traits x and y. Thus, $r_{x,y} = \sigma_{x,y}/(\sigma_x^2 x\ \sigma_y^2)^{1/2}$, in which $\sigma_{x,y}$ is the genetic covariance of traits x and y, σ_x^2 is the genetic variance of traits x and σ_y^2 is the genetic variance of trait y.

Heritability was estimated by the following method: $h^2 = \sigma_g^2 / \sigma_p^2$, in which h^2 is heritability involving the total genetic of variance. The phenotypic variance component (σ_p^2) was estimated directly from among populations mean square.

RESULTS AND DISCUSSION

Mean squares for grain quality characters are presented in Table 1. There were significant ($P < 0.05$) differences among populations for GWP, HGW, grain yield, GOC, and GPC but not for DTH in F1 generation. Significant variation was also observed in F2 generation for DTH, GWP, HGW, grain yield, GOC, and GPC. Except for HGW, variation on DTH, GWP, grain yield, GOC and GPC was greater in F2 than in F1 population.

Genotypic mean and ranges of the traits were presented in Table 2. On the average, genotypes in F1 could be harvest earlier, had smaller grain weight per plant, greater 100-grain weight, grain yield, oil content and protein content than those in the F2 generation (Table 2). However, the range was wider in the F2 that those in the F1 generation.

Table 1. Mean squares from analysis of variance of grain quality traits at F1, and F2 generation of soybean

Trait	F_1 Generation		F_2 Generation	
	Populations	Error	Populations	Error
Days to harvest (days)	30.36	10.636	99.710 *	11.342
Grain weight plant^{-1} (g)	119.01**	6.709	226.007 **	17.548
100- grain weight (g)	102.83*	11.767	64.545 **	12.987
Grain yield m^{-1} (g)	1412.32**	210.133	3759.540 **	373.502
Oil content (g kg^{-1})	31.85**	3.123	41.480 **	2.657
Protein content (g kg^{-1})	44.34**	3.832	78.090 **	4.543

*, ** significant at α 0.05 and 0.01, respectively

Table 2. Mean, range and standard error of several traits in F1 and F2 generations

Traits	F1 Population			F2 Population		
	Mean	Range	SE	Mean	Range	SE
Days to harvest	82.23	74.34 – 89.00	10.94	87.23	75.40 – 96.65	12.72
Grain weight plant^{-1}(g)	17.32	16.35 – 28.10	7.90	22.27	15.64 – 27.20	4.98
100-grain weight (g)	15.53	12.50 – 14.77	3.21	12.69	10.81 – 13.97	1.80
Grain yield m^{-2} (g)	124.56	113.26 – 161.25	13.20	100.45	81.24 – 172.50	15.44
Oil content (%)	16.89	14.47 – 18.20	1.76	15.68	15.03 – 16.39	16.70
Protein content (%)	40.31	26.77 – 48.07	28.97	32.24	26.59 – 45.72	34.06

Genotypic variance and heritability estimates are presented in Table 3. Except for days to harvest, genotypic variance in the F1 generation was considered significant for all traits as the values more than twice their standard error. The estimate of genotypic variance in the F2 generation, however, was significant for all characters.

Heritability ranging from 0.27 for protein content to 0.57 for 100 - grain weight in F1 and from 0.28 for grain oil content to 0.48 for 100 - grain weight was observed in the F2 generation (Table 3). The value was considered as different from zero if it is equal or more than its standard error (Hanson, 1987). So, the estimate of heritability which is significant from zero was only DTH, GWH, HGW and protein content both in the F1 and F2 generation. Aside from the significant value of heritability, the magnitude of heritability was higher in the F1 than that in the F2 generation, which inferred environmental factor played a major role in the traits in the F2 generation.

It was found that genetic correlation coefficients were generally greater in magnitude compare to simple correlation coefficients for all traits (Table 4). Positive correlation was observed between DTH to HGW and GWP and between HGW to grain yield and GPC. Grain protein content was negatively correlated to GWP and grain yield but positively correlated to HGW. There was no significant correlation between GOC and other traits.

Table 3. Estimates of Genetic variance (σ_g^2) and heritability (h^2), with standard errors in parentheses, for soybean grain quality

Traits	Genetic variance (σ_g^2)		Heritability (h^2)	
	F_1 generation	F_2 Generation	F_1 Generation	F_2 Generation
Days to harvest	6.34 (2.53)	3.223 (2.321)	0.54 (0.22)	0.44 (0.20)
Grain weight per plant	8.85 (3.76)	6.68 (2.87)	0.48 (0.23)	0.38 (0.12
100 - grain weight	6.62 (2.36)	4.88 (2.30)	0.57 (0.26)	0.48 (0.21)
Grain yield m^{-2}	211.90 (101.12)	271.54 (155.76)	0.32 (0.26)	0.32 (0.21)
Grain oil content	1.53 (0.65)	2.79 (1.14)	0.43 (0.24)	0.28 (0.23)
Grain protein content	2.64 (1.18)	3.84 (1.96)	0.27 (0.13)	0.32 (0.15)

Table 4. Simple (above diagonal) and genetic correlation (below diagonal) for several soybean yield components and grain quality traits in F_2 generation

Traits	DTH	GWP	HGW	Yield	GPC	GOC
Days to harvest (DTH)	-	0.33*	0.35*	0.21	-0.19	0.09
Grain weight plant^{-1} (GWP)	0.36 †	-	-0.58 *	0.39 *	0.29*	0.09
100- grain weight (HGW)	0.45 †	-0.29 †	-	-0.21	0.30*	0.29*
Grain yield m^{-2} (Yield)	0.22	0.19	0.36 †	-	-0.43**	-0.06
Protein content (GPC)	0.23	-0.35 †	0.52 †	-0.49†	-	-0.38*
Oil Content (GOC)	0.16	0.20	0.09	-0.08	-0.23	-

*, ** indicate significant at $p<0.05$ and $p<0.01$ respectively.
† indicates covariance exceeds its standard error.

DISCUSSION

Increased yielding ability and improved grain oil and protein content are among main objectives of recent soybean plant breeding program. This study revealed considerable genetic variation for some yield components and grain quality traits which indicated that these characters were potential for population improvement. This result supported previous finding reported by Panthee *et al.* (2005) and Lee *et al.* (1996).

Genotypic mean of most characters was greater in the F1 generation compared to those in the F2 generation, however; the ranges were wider in the F2 than those in the F1 generation. This result is understandable, because F2 plants has already undergone genotypic segregation both among and between plants within a population. The values of genotypic component of variance were significant for these two populations except for DTH and grain yield m^{-2} in the F2 population as also obtained by Aditya *et al.* (2011). So the data for the experiments indicated that there is substantial genotypic variation for grain quality and related characters among the soybean populations.

Estimates of heritability were relatively high for DTH, GWP, HGW and GPC both in F1 and F2 generations which inferred that the characters may be utilized as favorable indicators in selection program. Other characters such as grain weight per plant, grain yield and grain protein content were considered as more difficult to be modified in the reference population. The value of heritability for most characters observed in this study was smaller than that reported by Aditya *et al*. (2011) Burton & Brim (1981), Lee *et al*. (1996), Li & Burton (2002), and Jaureguy *et al*. (2011). The difference of heritability values observed in this study with the previous studies might be because the differences in method of estimation, and the differences in material used under studies. The value of heritability estimated in this study is broad sense estimate, which involved total genetic variance and might genetic by environment interaction components of variance.

Negative phenotypic and genetic correlations between grain yield m^{-2} and grain protein content found in this study would prevent a breeder to select a genotype having both high yielding ability and high grain protein content. If the breeder selects a new genotype having high grain protein content, a breeder will end up with a genotype with low grain yield. Aside from this negative correlation, however, a breeder is still able to do a joint selection which would end up a genotype with considerably high yielding ability and high grain protein content. Positive correlation coefficient between protein content and 100-grain weight is positive as also observed in other studies (Maestri *et al*., 1998; Yin & Vyn, 2005; Rasyad & Idwar, 2010) inferred the potential of 100-grain weight to serve as alternative selection criterion for grain protein content. The drawback of evaluating grain protein content in a great number of genotypes is time consuming and the method is more difficult. Indirect selection for high grain protein content by selecting greater grain weight would be easier in a soybean plant breeding practice. Since we did not find significant correlation between grain oil content and both grain yield and grain protein content, it is possible to select a variety with high grain yield and high grain oil content or a variety with high in both grain protein and oil content.

ACKNOWLEDGEMENT

This research was fully sponsored by the University of Riau under "Hibah Penelitian Guru Besar". The authors would like to express our sincere appreciation to the Rector of University of Riau for providing financial support of the research. We would also like to thank Ms Yelmida for her assistant in laboratory works.

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