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Correlation and path analysis for agronomic traits contributing to yield in 30 genotypes of soybean

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Abstract. *Karyawati AS, Puspitaningrum ESV. 2021. Correlation and path analysis for agronomic traits contributing to yield in 30 genotypes of soybean. Biodiversitas 22: 1146-1151.* To obtain more productive soybean genotypes, it is essential to know the contribution of each agronomic trait to the productivity of soybeans. The purpose of this study was to analyze the correlation and path analysis in thirty genotypes of soybeans (*Glycine max* (L.) Merrill) for eleven traits. The study was conducted in March-June 2019, in an experimental area located at Agro Techno Park, which belongs to Universitas Brawijaya, Malang, East Java Province, Indonesia. The experimental design was a randomized complete block design with three replications. Analysis of correlation showed that the number of branches, number of filled pods, number of seeds per plant, weight of 100 seeds, and weight of seeds per plant had a positive correlation value to the yield. Path analysis showed that the number of seeds per plant had a high positive, direct effect on the yield. The plant height, number of branches, fresh weight and dry weight had an indirect effect on the yield. Based on the result, the number of seeds per plant can be selected as one of the selection criteria in a soybean breeding program to obtain a high-yield soybean variety.

Keywords: Correlation, path analysis, soybean, yield

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a legume plant from the Fabaceae family (Akram et al. 2011). This plant is widely used by Indonesians either as a food ingredient, a mixture of animal feed, or an industrial raw material (Sa'diyah et al. 2011). Soybean has a high protein content of about 40% to 42%, the second-highest after peanuts and fat (18% to 22%) which consists of 85% unsaturated fatty acids and is free of cholesterol, so it is very good for health (Aondover et al. 2013). Apart from the nutritional contents contained in soybean, the increasing population of Indonesians also affects the amount of soybean needed for national consumption.

Based on data released by the Ministry of Agriculture, in the period of October 2018-October 2019, the local soybean production was stagnant at around 520,000 tons. At the same time, the consumption was estimated to reach 3.07 million tons, of which 95% is for the needs of the food sector; therefore, during that period Indonesia imported 2.5 million tons of soybeans.

One of the efforts to increase soybean production is by creating high production soybean varieties obtained through plant breeding programs (Mahbub and Shirazy 2016; Sudarić et al. 2019; Sulistyo and Sari 2018). An important step in plant breeding is the selection phase (Meira et al. 2016; Weltzien and Christinck 2017; Sulistyo and Sari 2018). The success and failure of the plant breeding depend on the ability of the plant to separate the superior genotypes through the selection process (Kuswantoro et al. 2018). The commonly used selection criteria are based on the characters of the yields or their components. The selection can be done directly and indirectly (Vu et al. 2019; Sulistyo and Sari 2018)). The existence of a correlation between characters causes the condition in which the selection applied to one character simultaneously includes other characters that are correlated with the selected one (Popović et al. 2012a,b; Dvorjak et al. 2019).

Knowledge of the correlation relationship between yields and their components can help design the soybean breeding programs to increase soybean yields (Ulloa et al. 2010; Machikowa and Laosuwan 2011; Weltzien and Christinck 2017). Soybean yield potential is also determined by several agronomic properties, such as the number of plants per unit area, the number of pods per plant, the number of seeds per plant, the seed weight, the number of branches per plant, the number of fertile nodes and the length of the branches (El Naim and Jabereldar 2010; Meira et al. 2016; Kyei-Boahen et al. 2017; Carciochi et al. 2019; Du et al. 2019; Tanzi et al. 2019). Thus, the knowledge of the relationship between these characters and their contribution to the soybean yields is very essential (Yahaya and Ankrumah 2015; Yahaya and Ankrumah 2017).

The correlation coefficient can be utilized to identify how significant a character changes if other characters change (Bello et al. 2012; Nagarajan et al. 2015; Teodoro et al. 2015). The relationship between these traits contributes to the improvement of genetic traits through an indirect selection of the less contributing traits (Machado et al. 2017). A simple correlation cannot accurately explain the cause and effect relationship between the yields and their components, so it is less efficient in the selection strategy (Baraskar et al. 2014). Therefore, the relationships of the traits contributing to the yields should be further analyzed using a path-analysis to identify the direct and indirect selection criteria (Sarutayophat 2012; Ghodrati et al. 2013; Mahbub et al. 2015; Chavan et al. 2016). This study aimed to examine the correlation and direct and indirect effects between yield traits and their components, using the path analysis method on 30 soybean plant genotypes.

MATERIALS AND METHODS

This research was carried out from March to June 2019 in the Experimental Garden of Universitas Brawijaya located in Agro Techno Park, Malang, East Java Province, Indonesia. The research site is at a position of 7°21'-7°31' South Latitude and 110°10'-111°40' East Longitude with an altitude of 330 m above sea level, an average air temperature of 25°C-30°C in alfisol soil. The field research employed a randomized block design (RBD) with three replications. The seeds used were the seeds of the F6 generation resulting from fully diallel hybridization of six species, including Anjasmoro (AJM), Tanggamus (TGM), Argopuro (AGP), Grobogan (GBG), Brawijaya 1 (UB 1), and Brawijaya 2 (UB 2). Thus, 30 genotypes resulting from the hybridization were obtained, including: AJM X TGM, AJM X AGP, AJM X GBG, AJM X UB1, AJM X UB2, TGM X AJM, TGM X AGP, TGM X GBG, TGM X UB1, TGM X UB2, AGP X AJM, AGP X TGM, AGP X GBG, AGP X UB1, AGP X UB2, GBG X AJM, GBG X TGM, GBG X AGP, GBG X UB1, GBG X UB2, UB1 X AJM, UB1 X TGM, UB1 X AGP, UB1 X GBG, UB1 X UB2, UB2 X AJM, UB2 X TGM, UB2 X AGP, UB2 X GBG and UB2 X UB1. There were 36 beds in each replication and each bed consisted of 60 plants with a spacing of 15x40 cm for a total of 6480 plants. NPK fertilizer (16:16:16) was given at a dose of 250 kg ha-1. Pest and disease controls were done manually. The observed characters included the fresh weight, the dry weight, the plant height, the stem diameters, the number of fertile nodes, the number of branches, the number of filled pods, the number of empty pods, the number of seeds per plant, the weight of 100 seeds and the weight of seeds per hectare. The data analyzed in the correlation matrix were plant phenotypes with 6 samples in each plot from plot average we used.

The data were analyzed using an analysis of variance (ANOVA) and analysis of covariance (ANCOVA), which was then analyzed further to determine the closeness of the relationship among the traits employing a simple correlation formula (Mode and Robinson 1959). Multicollinearity test was performed prior to traits analysis. If the tolerance value is more than 0.10, it means that multicollinearity does not occur. The correlation coefficient test between two traits was performed using the t test with degrees of freedom (n-2) (Vencovsky and Barriga 1992). The direct and indirect effects of the yield components on the seed yields were analyzed by using path analysis (Singh and Chaudhary 1992).

RESULTS AND DISCUSSION

ANOVA, ANCOVA and multicollinearity test between the yields and their components

ANOVA results showed that crosses between plant varieties had a significant effect on plant height, number of fertile books, number of branches, number of filled pods, number of seeds per plant, seed weight per plant, weight of 100 seeds, and weight of seeds per ha (Table 1). Meanwhile, the ANCOVA results showed that crossover had an effect on seed weight per ha with stem diameter, number of branches, fresh weight, dry weight, number of filled pods, number of seeds per plant, weight of 100 seeds, and weight of seeds per plant (Table 2). Prior to the traits test, we performed a multicollinearity test. This multicollinearity test is conducted to determine whether or not there is a deviation from the classic multicollinearity assumption. The requirements that must be met are the absence of multicollinearity by looking at the value of inflation factor (VIF) and tolerance. The multicollinearity test results showed that there were no deviations from the classical assumptions in all the observed parameters as indicated by the Tolerance value for all the observed parameters> 0.10 and the VIF value <10.00 (Table 3).

Correlation between the yields and their components

The correlation analysis results indicated that there were positive and negative correlations among the yield components (Table 4). The yield components which had a positive correlation with the seed yields were the dry weight (0.344*), the number of filled pods (0.639**), the number of seeds per plant (0.806**), and the weight of 100 seeds (1.000**). This indicates that an increase followed the increase in the dry weight, the number of filled pods, the number of seeds per plant, and the weight of 100 seeds in the seed weight per hectare. The highest positive correlation value (0.831**) was found in the correlation between the fresh weight and the dry weight. Besides the fresh weight trait, the trait of the number of filled pods also had a positive correlation with the trait of the number of seeds per plant. The positive correlation coefficient value was not significant as indicated in the correlation between the dry weight and the number of filled pods (r = 0.324). Meanwhile, a not significant negative correlation coefficient was found in the correlation between the fresh weight and the seed weight per plant.

Path analysis between the yield components and the seed yields

The correlation analysis results do not provide detailed information about the results of the relationship between the yield components and the traits of the yields. Path analysis was performed to determine the direct and indirect effects between the yield components and the yield traits. The path analysis results can be seen in Table 5, which contains the values of the direct and indirect effects of the yield traits on the yields (the weight of the seeds per hectare). To facilitate in reading the results of the path analysis, these results are also presented in the form of a diagram in Figure 1.

Table 1. ANOVA

Character	MS	CV
TT	91.43 **	8.89
DB	0.67 ns	10.60
JBS	5.50 **	6.71
JC	1.98 **	14.80
BS	1118.80 ns	20.64
BK	87.34 ns	20.44
JPI	1159.92 **	20.64
JPH	2.49 ns	55.44
JBT	4619.81 **	14.27
BBT	18.78 **	13.53
B100B	17.83 **	8.61
BBH	0.42 **	13.53

Note: TT: The plant height; DB: The stem diameter; JBS: The number of fertile nodes; JC: The number of branches; BS: The fresh weight; BK: The dry weight; JPI: The number of filled pods; JPH: The number of empty pods, JBT: The number of seeds per plant; B100B: The weight of 100 seeds; BBT: The seed weight per plant; BBH: The weight of seeds per hectare; ns: not significant. *: significantly different at 5%. **: significantly different at 1

Table 2. ANCOVA

Character	MS
TT x BBH	0.448 ns
DB x BBH	0.143 **
JBS x BBH	0.749 ns
JC x BBH	0.192 **
BS x BBH	11.876 **
BK x BBH	2.85 **
JPI x BBH	15.75 **
JPH x BBH	-0.244 ns
JBT x BBH	37.472 **
B100B x BBH	2.817 **
BBT x BBH	-1.479 **

Note: TT: The plant height; DB: The stem diameter; JBS: The number of fertile nodes; JC: The number of branches; BS: The fresh weight; BK: The dry weight; JPI: The number of filled pods; JPH: The number of empty pods, JBT: The number of seeds per plant; B100B: The weight of 100 seeds; BBT: The seed weight per plant; BBH: The weight of seeds per hectare; ns: not significant. *: significantly different at 5%. **: significantly different at 1

Table 3. Multicollinearity test

Character	Tolerance	VIF
TT	0.864	1.157
DB	0.702	1.425
JBS	0.791	1.264
JC	0.828	1.207
BS	0.251	3.990
BK	0.290	3.452
JPI	0.288	3.477
JPH	0.895	1.118
JBT	0.117	8.582
BBT	0.237	4.211
B100B	0.385	2.600
BBH	0.864	1.157

Note: TT: The plant height. DB: The stem diameter. JBS: The number of fertile nodes. JC: The number of branches. BS: The fresh weight. BK: The dry weight. JPI: The number of filled pods. JPH: The number of empty pods. JBT: The number of seeds per plant. B100B: The weight of 100 seeds. BBT: The seed weight per plant. BBH: The weight of seeds per hectare. Tolerance value > 0.10 and VIF <10.00 it means that multicollinearity does not occur.

Based on the path analysis results, the main trait that had a significant, direct effect on the weight of the seeds per hectare was the weight of 100 seeds. For the stem diameter trait, the dry weight and the number of empty pods directly affected. Meanwhile, the traits of the plant height, the number of fertile nodes, the number of branches, the fresh weight, the dry weight, the number of filled pods, the number of empty pods, the number of seeds per plant, and the seed weight per plant had a direct negative effect. The results of the path analysis showed that the weight of 100 seeds had an indirect effect on the yields through the number of seeds per plant (0.80729), the number of filled pods (0.64036), the fresh weight (0.32247), and the dry weight (0.34366).

Discussion

The components of the correlation analysis results show information in the form of a negative and positive correlation. If the resulting correlation value is positive, then increasing the first component will increase the second component. However, if the resulting correlation value is negative, then increasing the first component will decrease the second component (Saputra et al. 2016). The correlation result means that an increase will follow every increase that occurs in the first character in the second character. An increase will follow each increase in the character weight of 100 seeds in the character weight of seeds per hectare. This is by the research (Hakim 2017), that the weight of 100 seeds has a significant positive correlation with seed weight and has a significant correlation with the harvest index, which indicates that large soybean varieties can have high seed weight and harvest index. This shows that the relationship between the two characters is very strong and the weight of 100 seeds is one of the determinants of the harvest index.

In addition to the character weight of 100 seeds, the character of the number of seeds per plant and the number of filled pods also had a high correlation value to the character of the seed weight per hectare. In this case, the correlation between characters on the number of filled pods and the number of seeds per hectare has a positive correlation value, so the higher the value of the number of seeds per plant will also be followed by an increase in the number of filled pods so that these two characters directly affect the increase in seed weight per hectare. This is following the results of research by Aditya et al. (2011) and Aondover et al. (2013) that the number of filled pods per plant shows a very significant positive correlation with the character of seed yield per plant.

The character of the number of filled pods also had a positive correlation with the character of seed weight per plant, where each increase in the character of the number of filled pods would increase the character of the weight of seeds per plant. This can happen because if the number of filled pods increases, the number of seeds per plant will also increase and directly affect the weight of seeds per plant. This is consistent with the results of research by Saputra et al. (2016) that the total number of pods has the greatest direct effect on seed weight per plant and has

Table 4. The results of correlation analysis among the yield components

Traits	TT	DB	JBS	JC	BS	BK	JPI	JPH	JBT	B100B	BBT
DB	0.135ns										
JBS	0.208ns	0.052ns									
JC	-0.096ns	0.027ns	-0.175ns								
BS	0.192ns	0.368*	0.205ns	0.122ns							
BK	0.161ns	0.268ns	0.171ns	0.193ns	0.831**						
JPI	0.003ns	-0.047ns	0.211ns	0.168ns	0.363*	0.324ns					
JPH	-0.048ns	-0.008ns	-0.18ns	-0.041ns	0.061ns	-0.003ns	-0.058ns				
JBT	0.011ns	0.067ns	0.26ns	0.254ns	0.401*	0.392*	0.83**	-0.084ns			
B100B	0.107ns	0.244ns	0.274ns	0.208ns	0.322ns	0.343*	0.64**	-0.081ns	0.807**		
BBT	-0.07ns	0.114ns	-0.192ns	-0.225ns	-0.264ns	-0.257ns	0.614**	0.197ns	-0.682**	0.36*	
BBH	0.107ns	0.244ns	0.273ns	0.207ns	0.322ns	0.344*	0.639**	-0.08ns	0.806**	1.000**	0.36*

Note: TT: The plant height. DB: The stem diameter. JBS: The number of fertile nodes. JC: The number of branches. BS: The fresh weight. BK: The dry weight. JPI: The number of filled pods. JPH: The number of empty pods. JBT: The number of seeds per plant. B100B: The weight of 100 seeds. BBT: The seed weight per plant. BBH: The weight of seeds per hectare. ns: not significant. *: significantly different at 5%. **: significantly different at 1%

Table 5. Path analysis between the yields and their components

Traits	Indirect Effect through Traits										
	TT	DB	JBS	JC	BS	BK	JPI	JPH	JBT	B100B	BBT
TT	-0.00012	0.00006	-0.00021	0.00006	-0.00042	0.00039	-0.00000	-0.00005	-0.00000	0.10735	0.00003
DB	-0.00002	0.00047	-0.00005	-0.00002	-0.00080	0.00064	0.00004	-0.00001	-0.00002	0.24424	-0.00005
JBS	-0.00002	0.00002	-0.00102	0.00011	-0.00045	0.00041	-0.00020	-0.00018	-0.00008	0.27445	0.00008
JC	0.00001	0.00001	0.00018	-0.00063	-0.00027	0.00046	-0.00016	-0.00004	-0.00008	0.20785	0.00009
BS	-0.00002	0.00017	-0.00021	-0.00008	-0.00218	0.00199	-0.00034	0.00006	-0.00012	0.32247	0.00011
BK	-0.00002	0.00013	-0.00018	-0.00012	-0.00181	0.00240	-0.00030	-0.00000	-0.00012	0.34366	0.00010
JPI	-0.00000	-0.00002	-0.00022	-0.00011	-0.00079	0.00078	-0.00094	-0.00006	-0.00025	0.64036	0.00025
JPH	0.00001	-0.00000	0.00018	0.00003	-0.00013	-0.00001	0.00005	0.00098	0.00003	-0.08124	-0.00008
JBT	-0.00000	0.00003	-0.00027	-0.00016	-0.00087	0.00094	-0.00078	-0.00008	-0.00030	0.80729	0.00028
B100B	-0.00001	0.00011	-0.00028	-0.00013	-0.00070	0.00082	-0.00060	-0.00008	-0.00024	1.00094	0.00015
BBT	0.00001	0.00005	0.00020	0.00014	0.00058	-0.00062	0.00057	0.00019	0.00020	-0.36060	-0.00041
Residual	0,00003										

Notes : TT: The plant height. DB: The stem diameter. JBS: The number of fertile nodes. JC: The number of branches. BS: The fresh weight. BK: The dry weight. JPI: The number of filled pods. JPH: The number of empty pods. JBT: The number of seeds per plant. B100B: The weight of 100 seeds. BBT: The seed weight per plant. BBH: The weight of seeds per hectare, R: The residual val,

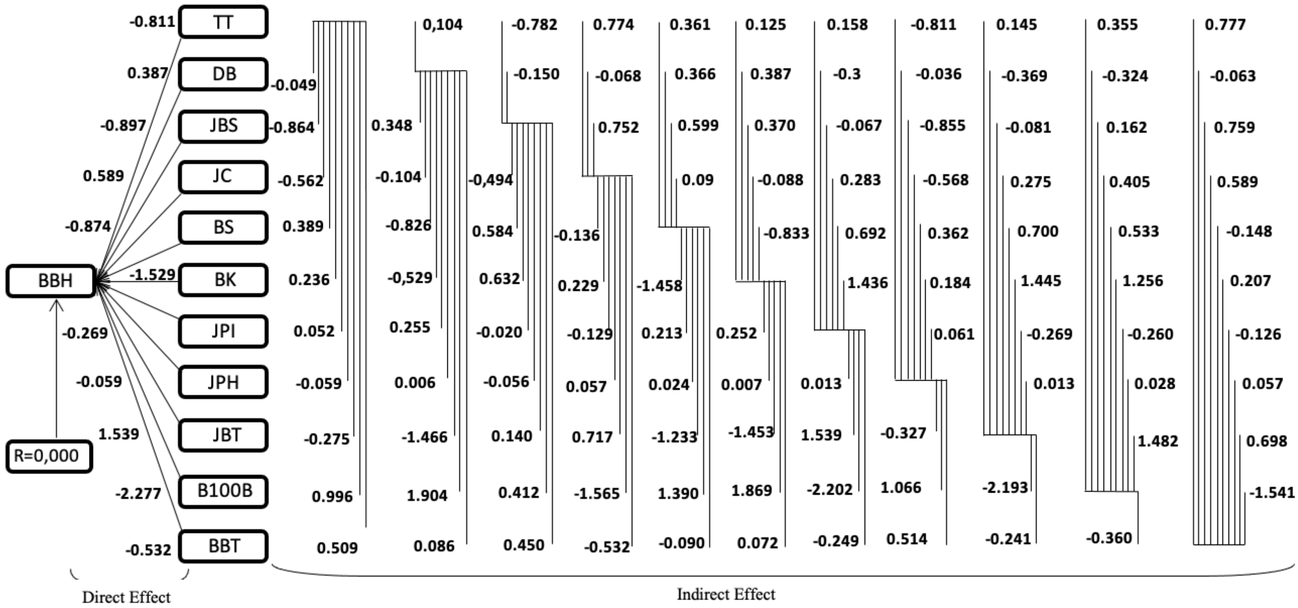

Figure 1. Path analysis of the yields of 30 soybean lines. Note: TT: The plant height. DB: The stem diameter. JBS: The number of fertile nodes. JC: The number of branches. BS: The fresh weight. BK: The dry weight. JPI: The number of filled pods. JPH: The number of empty pods. JBT: The number of seeds per plant. B100B: The weight of 100 seeds. BBT: The seed weight per plant. BBH: The weight of seeds per hectare, R: The residual value

almost the same correlation value. This shows that plants with a large number of pods will produce heavier seed weight values per plant so that it can directly affect the increase in seed weight per hectare.

The fresh weight character has a very significant positive correlation value to the dry weight character. Where an increase will follow each increase in fresh weight character in dry weight character. This can occur because the mass of the plant when it is fresh is directly proportional to the mass of the plant when it is dry.

Based on the cross coefficient analysis results, the main character that has a large direct effect on the weight of seeds per hectare is the weight of 100 seeds. For the character of stem diameter, dry weight and number of empty pods had a positive direct effect. While the characters of plant height, number of fertile books, number of branches, fresh weight, dry weight, number of filled pods, number of empty pods, number of seeds per plant, and seed weight per plant had a direct negative effect. The analysis results are by Hakim's (2017) research, which states that yield components such as the number of fertile books, plant height, and seed weight have an indirect effect on seed yield.

The results of path analysis on the character weight of 100 seeds on yield had an indirect effect through the characters of the number of seeds per plant, the number of filled pods, fresh weight, and dry weight. Fresh weight can affect dry weight, where the high fresh weight will also increase dry weight. This is following the value of the direct effect on the weight character of 100 seeds, which has the highest value so that the character of the seed weight per hectare is also higher. This is supported by the statement of (Jadeja et al. 2016) that the weight character of 100 seeds has the maximum contribution in determining soybean yield. According to Hakim (2012) and Mahbub et al. (2016), the morphological characters and yield components play an important role in soybean yield, one of which is the character of the number of filled pods plant.

The residual value has the meaning of the total value of the direct effect of the other characters (unidentified characters) that have not been calculated. According to Wijaya et al. (2015) and Putra et al. (2020), if the residual value is close to zero, the cross-fingerprint analysis used is more effective in explaining the cause and effect of the observed correlation and character values to more fully explain the direct and indirect effects of the results.

Based on the research results, it can be concluded that the yield component traits that have a positive correlation value with the yields (the seed weight per hectare) are the number of filled pods, the number of seeds per plant and the weight of 100 seeds. Meanwhile, the path analysis results show that the seed weight per hectare is influenced directly by the weight of 100 seeds and indirectly by the number of filled pods and the number of seeds per plant. The trait of the number of seeds per plant can be selected as one of the selection criteria in soybean breeding programs to obtain soybean varieties with high yield potential.

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