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GENETIC VARIABILITY, HERITABILITY AND RELATIONSHIPS OF YIELD AND YIELD CONTRIBUTING CHARACTERS IN INTRODUCTION KIDNEY BEANS

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Abstract: This research aims to study genetic parameters in the form of the genetic coefficient of variation and broad-sense heritability as well as the closeness of the relationship between the yield and the yield contributing characters of introduced kidney beans of Timor Leste and its direct and indirect effects through correlation and path analysis. This research was conducted at the Djuanda University experimental field, Ciawi, Bogor, in August-November 2020. The research design used was a randomized complete block design (RCBD) with kidney bean accessions as a factor and was repeated 4 times. The results showed that a fairly wide genetic variation was found in leaf area characters and a rather narrow genetic variation was found in the number of pods, number of empty pods, number of full pods, wet pod weight, dry pod weight, and seed weight characters, while the rest had a narrow genetic variation. Most of the characters had high heritability values, except for leaf area, number of branches, number of empty pods, pod length, and number of seeds per pod. The character of days to harvesting had a significant and negative correlation with the yielding character, namely seed weight, while the characters for the number of pods and the number of full pods had a significant and positive correlation. The character of seedling emergence percentage had the highest direct effect on seeds weight, while the number of pods and the number of full pods had a low direct effect but a high indirect effect through the characters of the number of seeds per pod and number of branches.

Keywords: genetic variability; heritability; kidney; plant breeding; selection; yield

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1. INTRODUCTION

Kidney beans are a type of legume plant that has high nutritional content, so it has a role in fulfilling the nutritional adequacy of the Indonesian people. According to Gouveia et al. (2014), 100 g of kidney bean seeds contained 3.64-5.67% ash, 0.57-2.86% fat, 18.55-29.69% protein, and 23.40-52.65% carbohydrates. Several water-soluble vitamins such as thiamin, riboflavin, niacin, vitamin B6, folic acid, and minerals such as potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), and iron (Fe) were found in kidney beans (Celmeli et al., 2018). Kidney beans have a high selling value and are consumed by boiling them, making them a salad mixture, making chili sauce, and fried peanuts (Ndakidemi et al., 2006).

The main problem in kidney bean production is the low yield of the plant. The national variety of Indonesian kidney beans are not yet available until now, so farmers still use local accessions with low productivity because the genotypes are still mixed. Based on the test results of (Sumpena et al., 2013) on the nine expected kidney bean lines, it is known that the average yield of kidney beans in Indonesia ranges from 370-2,000 kg ha-1. Meanwhile, kidney bean production in Brazil ranges from 863-2,084 kg ha-1 and in Ethiopia ranges from 2,000-3,000 kg ha-1 (Guimarães et al., 2011;Masa et al., 2017).

Efforts to improve kidney bean yields can be carried out through plant breeding programs, namely through introduction and selection activities. The introduction is the activity of moving the species of a plant from abroad into the country to be released as an introduced variety or used as cross material with local cultivars that have adapted well (Nazirwan et al., 2014). The introduced kidney beans used in this study were Timor Leste accessions. Timor Leste has a fairly high genetic diversity of kidney beans and climatic and geographic conditions that are not too different from Indonesia, so it is hoped that it can support and accelerate the kidney bean breeding program in Indonesia.

Selection activities for quantitative characters, especially yield characters, are generally difficult to do because of the high influence of the environment and control of expression by many genes (Weinig & Schmitt, 2004). However, the selection of the yield characters can be effective if the values of genetic parameters are known, such as the genetic coefficient of variation (GCV) and the broad-sense heritability value (Saha et al., 2019). The genetic variation of a population is one of the basic considerations in selection programs, while the heritability value will indicate the inheritance of the character to the next generation (Adhikari et al., 2018). In addition to genetic parameters, it is also necessary to know information related to the closeness of the relationship and influence between yield and yield contributing characters (Abdullah et al., 2008). Therefore, this research aims to study genetic parameters in the form of the genetic coefficient of variation and broad-sense heritability as well as the closeness of the relationship between the yield and the yield contributing characters of introduced kidney beans of Timor Leste and their direct and indirect effects through correlation and path analysis.

2. METHODS

The research was carried out in August-November 2020 in the experimental field of Djuanda University, Jalan Tol No. 1, Po Box 35, Ciawi, Bogor (± 400 m asl). The plant material used was 5 introduced kidney bean accessions of Timor Leste and 1 local accession of Cipanas, Indonesia as a comparison. The research design used was a randomized complete block design (RCBD) with accession as a factor and repeated 4 times. Other materials used were manure, urea fertilizer, SP-36 and KCL, stakes, insecticides, and fungicides. Meanwhile, the equipment used were the cultivation tools, stationery, kidney bean descriptors, measuring tools, labels, clear plastic bags, seed bags, seedboxes, digital cameras, Thermohygrometer, digital scales, and analytical balance.

2.1. Procedures

The research was started by making 3 large plots measuring 32 m x 2.5 m with the space between the plots of ± 1 m and the plant spacing of 50 cm x 50 cm. Manure applied one week before planting with a dose of 15 t ha-1. Planting was carried out together with the application of urea fertilizer at a dose of 75 kg ha-1, SP-36 100 kg ha-1, and KCl 100 kg ha-1. Dead plant replacement was carried out when the plants were 14 days after planting together with the installation of stakes for spread media. Weed removal was carried out once a week, while the

earthing up was once every two weeks. Harvesting was carried out when the plants enter the physiological ripe phase by hand-picking and done once every two days until all the fruit was ripe. Drying was carried out by drying it in the sun for ± 14 days.

2.2. Observation Variables

In this study, observations were made on 4 sample plants for each experimental unit, except for the days of flowering and days of harvesting variables which were observed in all plants for each accession. The variables observed following IBPGR for kidney beans, namely seedling emergence percentage, plant height, number of leaves, leaf area, number of branches, stem diameter, days to 50% flowering, days to harvesting, wet pod weight, dry pod weight, number of seeds per pod, length pods, number of empty pods, number of full pods and seed weight per plant (IBPGR, 1982).

2.3. Data Analysis

The quantitative data that had been recapitulated were analyzed using SAS and R software. Variance analysis was performed to see the effect of accession on the observed characters. The value of the variance components were estimated using the middle square and the expected value based on Singh & Chaudhary (1979) formula. The heritability value was then categorized based on (Syukur et al., 2011), with the criteria of high (50% <h2<100%), moderate (20% ≤h2≤ 50%), and low (h2<20%) . The estimation of the GCV was calculated based on the research formula of Singh & Chaudhary (1979) with the value category based on Effendy et al. (2018), namely the GCV is low (0% ≤ 25%), rather low (25% ≤ 50%), quite high (50% ≤ 75%) and high (75% ≤ 100%).

The value of the correlation coefficient was calculated using the formula of Walpole (1982) and the correlation coefficient value calculated was used in the calculation of the path coefficient using the (Singh & Chaudhary, 1979) formula.

3. RESULTS AND DISCUSSION

3.1. Variance Analysis, Heritability and Genetic Coefficient of Variation

Based on the results of the variance analysis, it was found that almost all significant characters were affected by kidney bean accession, except for the number of empty pods (Table 1). The Ethiopian bean cultivars tested by (Amanuel et al., 2018) gave a similar response. The test results indicated that all observed characters such as root length, nodule number per plant, days to 50% flowering, days to harvesting, number of pods per plant, pod length, and number of seeds per pod were significantly influenced by the cultivar of kidney beans. The significance of the variance analysis results indicated that there was variation among the introduced kidney bean accessions of Timor Leste.

Heritability is a statistical genetic study that can provide an estimate of the number of phenotypic variations in a population caused by genetic variance (Visscher et al., 2008). In this study, the estimated heritability value was broad sense heritability which is obtained from a comparison between total genetic variation and phenotype variation (Hadi et al., 2019). Information on heritability value is needed to increase the effectiveness in the selection of superior plant genotypes because it can be seen to what extent a character can be inherited. The high heritability value was represented in the genetic variance value that was higher than the environmental range value (Table 2).

Based on Table 2, it is known that almost all characters have high heritability values. Seedling emergence percentage (89.47%), plant height (88.31%), number of leaves (62.18%), stem diameter (75.13%), days to 50% flowering (93.33%), days to harvesting (75.13%), number of pods (81.66%), number of full pods (82.17%), the weight of wet pods (66.25%), the weight of dry pods (83.87%), and weight of seeds (69, 78%) characters have a relatively high heritability value. This indicates that the phenotypes of these characters were more influenced by genetic factors than environmental factors so that they can be considered as selection characters (Wirnas *et al.*, 2006). Meanwhile, characters such as leaf area (32.84%), number of branches (39.02%), number of empty pods (26.23%), pod length (48.83%), and number of seeds per pod (45.40%) have moderate heritability values. Jhanavi et al. (2018) reported a similar result, where the kidney beans tested had heritability values ranging from 63.32% to 85.36% and were classified as high.

Table 1 Variance analysis result, predictive value of variance components, heritability, and genetic coefficient of variation of introduced and comparable kidney bean accessions

Characters	F value	V_e	V_g	V_p	h^2_{bs} (%)	GCV
Seedling emergence (%)	35.0*	26.25	222.94	249.19	89.47	16.29
Plant height (cm)	31.2*	228.52	1725.74	1954.25	88.31	19.56
Number of leaves	7.6*	20.08	33.01	53, 08	62.18	15.31
Leaf area (cm2)	3.0*	980.1	479.21	1459.31	32.84	58.33
Number of branches	3.6*	0.48	0.31	0.79	39.02	13.63
Diameter stem (cm)	13.1*	0.25	0.76	1.01	75.13	13.97
Flowering (days)	57.0*	1.38	19.25	20.63	93.33	10.42
Harvesting (days)	13.1*	1.98	5.97	7.94	75.13	3.37
Number of pods	18.8*	13.44	59.83	73.27	81.66	44.89
Number of empty pods	2.4in	0.86	0.31	1.17	26.23	40.79
Number of full pods	19.4*	58.88	12.78	71.66	82.17	48.35
Wet pod weight	8.85*	12.15	23.85	36	66.25	40.09
Dry pod weight	21.8*	4.5	23.39	27.89	83.87	47.99
Pod length	4.8*	0.44	0.42	0.86	48.83	5.79
Number of seeds per pod	4.3*	0.26	0.21	0.47	45.4	9.73
Seed weight	10.2*	2.45	5.66	8.11	69.78	35.7

* statistically significant, in statitiscally insignificant, V_e = environmental variation, V_g = genetic variation, V_p = phenotypic variation, h^2_{bs} = broad sense heritability, GCP = genetic coefficient of variation

Some of the introduced kidney bean characters have a low genetic coefficient of variation values, such as seedling emergence (16.29%), plant height (19.56%), number of leaves (15.31%), number of branches (13.63%), stem diameter (13.97%), days to 50% flowering (10.42%), days to harvesting (3.37%), pod length (5.79%), and number of seeds per pod (9.73%). Meanwhile, number of pods (44.89%), number of empty pods (40.79%), number of full pods (48.35%), wet pod weight (40.09%), dry pod weight (47.99%) %), and seed weight (35.70%) genetic coefficient of variation was quite low. The leaf area character has the highest GCV value with a value of 58.33% and it is quite high. The higher the GCV value indicates the wider variation caused by genetic factors in the population (Ahsan et al., 2015). Ghimire & Mandal (2019) reported that accessions of kidney beans from Nepal had a similar GCV value range, namely 7.21%-34.01% with low to quite low categories.

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3.2. Correlation and Path Analysis

The results of the correlation analysis between the characters of introduced kidney beans of Timor Leste are presented in Table 2. In the table, it can be seen that almost all of the characteristics of kidney beans do not have a significant correlation with the character of the seed weight as a yielding character of a kidney bean. According to (Prabowo et al., 2014), the correlation that is not significant shows that the relationship between these characters is not close.

Days to harvesting character has significant and negative correlation coefficient values with the yield characters of kidney beans, such as number of pods (r = -0.90 *), number of full pods (r = -0.90 *), and seed weight (r = -0.91 *). This result is different from the result obtained by Kumar et al. (2014), who reported that the days to harvesting character had a positive correlation with kidney beans yield character. A negative correlation coefficient indicates that an increase in the value of one character will be followed by a decrease in the value of other characters (Saputra et al., 2017). The negative correlation between characters is generally undesirable, but a negative correlation between yield characters and days to harvesting is desirable. The negative correlation between yield characters and days to harvesting indicates that there are opportunities to obtain high-yielding accessions with early harvesting.

Table 2 Correlation between introduced kidney bean agronomic characters

car	TT	JD	LD	JC	DB	UB	UP	BPB	BPK	Jbij.pol	PP	JPC	JP	JPB	BBijB
DT	-0,05	0,61	0,21	0,33	0,39	-0,38	-0,21	0,26	0,27	0,50	-0,25	0,82*	-0,01	-0,06	0,23
TT		-0,64	0,27	-0,07	-0,72	-0,03	0,68	-0,33	-0,25	0,16	0,14	0,30	-0,55	-0,55	-0,66
JD			-0,11	0,54	0,79	0,20	-0,33	0,27	0,16	0,62	-0,69	0,46	0,01	0,01	0,19
LD				-0,45	0,15	-0,29	-0,28	-0,15	-0,07	-0,09	-0,18	0,13	0,06	0,04	0,10
JC					0,41	0,67	0,56	-0,41	-0,50	0,75	-0,38	0,67	-0,72	-0,73	-0,50
DB						0,26	-0,40	-0,16	-0,22	0,23	-0,42	0,25	0,03	0,01	0,33
UB							0,60	-0,62	-0,73	0,48	-0,47	0,09	-0,73	-0,69	-0,71
UP								-0,65	-0,67	0,42	0,00	0,36	-0,90*	-0,90*	-0,91*
BPB									0,99*	-0,05	-0,10	-0,18	0,73	0,74	0,54
BPK										-0,15	0,01	-0,19	0,78	0,78	0,59
Jbij.pol											-0,79	0,78	-0,65	-0,64	-0,59
PP												-0,37	0,32	0,29	0,36
JPC													-0,57	-0,62	-0,34
JP														1,00*	0,91*
JPB															0,88*

* significantly correlated at the 5% level, car = characters, DT = seedling emergence, TT = plant height, JD = number of leaves, LD = leaf area, JC = number of branches, DB = stem diameter, UB = days to 50% flowering, UP = days to harvesting, JP = number of pods, JPB = number of full pods, JPC = number of empty pods, BPB = weight of wet pods, CPC = weight of dry pods, PP = pod length, JBPol = number of seeds per pod, BW = seed weight

Two characters were significantly and positively correlated with the seed weight character of kidney beans, namely the number of pods (r = 0.91 *) and the number of full pods (r = 0.88 *). The same results were obtained by Jasim & Esho (2019) and stated that the character of the number of pods had a significant and positive correlation with seed yield per plant. Significantly positive correlation coefficients indicate that an increase in one character will be followed by an increase in another character (Sulistyowati et al., 2016).

Path analysis needs to be done because correlation analysis only explains the relationship between characters but does not provide information about the influence between characters.

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Based on the statement of (Safuan et al., 2014), path analysis is an analytical method that allows explaining the closeness of the relationship between variables through the decomposition of correlation coefficients into direct and indirect effects. A character is said to have a direct effect if it has direct influence without going through the intermediary of other characters (Sa'diyah et al., 2020). Meanwhile, the indirect effect is a condition in which a character has an influence on other characters through the intermediary of other characters (Soares et al., 2017). The direct and indirect influence between the characters presented in Table 3.

Table 3 Direct and indirect effects between introduced kidney beans agronomic characters

Car	DE	Indirect effects															Total
		DT	TT	JD	LD	JC	DB	UB	UP	BPB	BPK	JBPol	PP	JPC	JP	JPB	
DT	0,66	-	0,0	0,1	0,0	-0,1	0,0	-0,2	0,0	0,1	0,0	-0,6	0,0	0,2	0,0	0,0	0,23
TT	-0,18	0,0	-	-0,1	-0,1	0,0	-0,1	0,0	0,0	-0,1	0,0	-0,2	0,0	0,1	-0,2	0,2	-0,66
JD	0,17	0,4	0,1	-	0,0	-0,2	0,1	0,1	0,0	0,1	0,0	-0,7	0,1	0,1	0,0	0,0	0,19
LD	-0,20	0,1	0,0	0,0	-	0,2	0,0	-0,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,10
JC	-0,45	0,2	0,0	0,1	0,1	-	0,0	0,3	0,0	-0,1	0,0	-0,9	0,0	0,2	-0,2	0,3	-0,50
DB	0,11	0,3	0,1	0,1	0,0	-0,2	-	0,1	0,0	0,0	0,0	-0,3	0,0	0,1	0,0	0,0	0,33
UB	0,43	-0,3	0,0	0,0	0,1	-0,3	0,0	-	0,0	-0,2	0,0	-0,6	0,1	0,0	-0,3	0,2	-0,71
UP	0,00	-0,1	-0,1	-0,1	0,1	-0,3	0,0	0,3	-	-0,2	0,0	-0,5	0,0	0,1	-0,3	0,3	-0,91
BPB	0,25	0,2	0,1	0,0	0,0	0,2	0,0	-0,3	0,0	-	0,1	0,1	0,0	-0,1	0,3	-0,3	0,54
BPK	0,07	0,2	0,0	0,0	0,0	0,2	0,0	-0,3	0,0	0,2	-	0,2	0,0	-0,1	0,3	-0,3	0,59
JBPol	-1,19	0,3	0,0	0,1	0,0	-0,3	0,0	0,2	0,0	0,0	0,0	-	0,1	0,2	-0,2	0,2	-0,59
PP	-0,12	-0,2	0,0	-0,1	0,0	0,2	0,0	-0,2	0,0	0,0	0,0	0,9	-	-0,1	0,1	-0,1	0,36
JPC	0,29	0,5	-0,1	0,1	0,0	-0,3	0,0	0,0	0,0	0,0	0,0	-0,9	0,0	-	-0,2	0,2	-0,34
JP	0,35	0,0	0,1	0,0	0,0	0,3	0,0	-0,3	0,0	0,2	0,1	0,8	0,0	-0,2	-	-0,3	0,91
JPB	-0,34	0,0	0,1	0,0	0,0	0,3	0,0	-0,3	0,0	0,2	0,1	0,8	0,0	-0,2	0,3	-	0,88
Total	-0,18																
Residual	0,08																

car = characters, DT = seedling emergence, TT = plant height, JD = number of leaves, LD = leaf area, JC = number of branches, DB = stem diameter, UB = days to 50% flowering, UP = days to harvesting, JP = number of pods, JPB = number of full pods, JPC = number of empty pods, BPB = wet pod weight, BPK = dry pod weight, PP = pod length, JBPol = number of seeds per pod, DE=direct effect

The results of path analysis show that almost all characters had an indirect effect greater than the direct effect on the yield characters of seed weight. The character that gave the highest direct effect was seedling emergence of 0.66, but its indirect effect was only 0.23. The number of pods and number of full pod characters had low direct effects but had a high indirect effect with a value of 0.91 and 0.88 through the number of seeds per pod character with an effective value of 0.8 and the number of branches character with a value each effect 0,3. The results of path analysis conducted by (AlBallat & Al-Araby, 2019) on kidney beans from Egypt showed different results from this study. Based on their path analysis, the character of plant height and number of pods had the highest direct effect on kidney bean seed weight and all characters had a relatively high indirect effect.

4. **CONCLUSION**

A fairly wide genetic variation was found in leaf area characters and a rather narrow genetic variation was found in the number of pods, number of empty pods, number of full pods,

wet pod weight, dry pod weight, and seed weight characters, while the rest had a narrow genetic variation. Most of the characters had high heritability values, except for leaf area, number of branches, number of empty pods, pod length, and number of seeds per pod. The character of days to harvesting had a significant and negative correlation with the yielding character, while the characters for the number of pods and the number of full pods had a significant and positive correlation. The character of seedling emergence had the highest direct effect on seed weight, while the number of pods and the number of full pods had a low direct effect but a high indirect effect through the characters of the number of seeds per pod and number of branches.

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