

Estimation of genetic parameters on F3 French Bean (*Phaseolus vulgaris* L.) population

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Abstract. This research was aimed to study and to estimate the variance components, broad sense heritability, genetic advance, expected of genetic advance, correlation, direct effect, and indirect effect from several characters to potential yield. This research conducted at the Pusat Kajian Hortikultura Tropis (PKHT) IPB experimental field in Tajur and Plant Breeding Laboratory, Department of Agronomy and Horticulture, IPB. Population used the P1 (BCS-3), P2 (BCS-7), and F3 (BCS-3 x BCS-7) genotypes. The single plant method was used in this observation. The time of flowering, time of harvest, pod weight, pod diameter, pod length, seed per pod and 100 seed weight were had low genetic variability. The pod beak length, pod total per plant and yield potential characters were had medium genetic variability. The time of flowering, time of harvest, pod beak length, seed per pod, pod per plant, and yield potential were had medium to high of broad sense heritability with high genetic advance. Then, 100 seeds weight was had low heritability with high genetic advance. The pod length, pod diameter, and pod weight were had low heritability and low genetic advance. A positive correlation and a higher direct effect to yield potential were showed by the pod weight and pod total per plant. Some qualitative references were suggested become important characters for improving french bean yield in this population.

Keywords: *correlation, direct effect, french bean, genetic advance, heritability, qualitative, variability*

1. Introduction

French bean is being became a common pod vegetable consumption for Indonesian people. French bean consumption per person increases every year [1]. French bean consumption per person about 0.886 kg in 2011 increased up to 1.147 kg in 2015. French bean production in Indonesia decreased from 336.494 ton in 2010 to 318.378 ton in 2014 [2]. The unbalance consumption rate and production will be becoming a problem. Hence, high yielding french bean varieties have been assembling by the breeders currently.

French bean varieties have been created for marketing purpose. The beginning of this program was the hybridization. Selection in hybrid population can be created progenies as new variety candidate. The characters which had high variation has been becoming the most important requirements among lines to effective selection. Plant variances, like dwarf and vines plant determination, are had high adaption performance in different environments and different harvest time. The dwarf plant has an early harvest time for 60 – 70 days after planting than vines plant. The adapted



environment is differed by the plant determination. The vines plant has adapted in highland (1.000 – 1.500 m asl) and the dwarf plant has adapted in lowland (200 – 300 m asl) [3].

However, the high temperature on lowland will be influenced that affected on genetic and phenotype parameters especially for vines plants type was lacking in the studies. Different location altitude and field condition can be changed plants behavior. The pod quality, especially vines plant type that adapted on highland can be affected by the high temperature. Malformed, undeveloped, and curved pod, reduce of pod length, rough texture, poor quality on french bean pod can be caused by the drought [4]. The selection criteria have been selected to improve the breeder's work efficiency. The variance, heritability, correlation and path coefficient should be became the important selection criteria. We hypothesized that some quantitative characters could be becoming the direct effect on french bean yield production and the qualitative characters could be used as a references criteria. Further, the quantitative and qualitative characters should be used on the main character in the next selection for lowland french bean improvement.

This study was aimed to study and to estimate the variance components, broad sense heritability, genetic advance, expected of genetic advance, correlation, direct effect, and indirect effect from several characters of french bean to yield potential.

2. Material and methods

This study was conducted on January – June 2017 in Pusat Kajian Hortikultura Tropis IPB (PKHT) experimental field at an altitude of 250 m asl and the average of rainfall about 3.500 – 4.000 mm annually. The P1, P2, and F3 generations of french bean seed were used. The BCS-3 was the P1 genotype which has had a purple stem, vines plant, black seed, and pink flower. The BCS-7 was the P2 genotype which has had a green stem, vines plant, white seed, and white flower. Single plant observation was used in this study. The average, variance, genetic variance coefficient, broad sense heritability, genetic advance, expected genetic advance, correlation, and path analysis were used to analyze and to interpret.

The qualitative and quantitative characters was refered to the *Phaseolus vulgaris* L. descriptor [5]-[7]. The hypocotyl color, cotyledon color, leaf rugosity, pod shape, degree of pod curvature, pod beak shape, stem color, pod stringiness, pod texture, flower color, seed color, seed glossiness, and pod color intensity were defined by the qualitative characters. The time of flowering (days), time of harvest (days), pod beak length (mm), pod diameter (mm), pod length (cm), seed per pod (seed), pod weight (g), pod per plant (pod), 100 seed weight (g), and yield potential per plant (g) were defined by the quantitative characters. The T-test on 95% probability was used to compare the qualitative characters and potential yield average to know the difference level of each qualitative criteria.

3. Result and discussion

The hybrid of BCS-3 x BCS-7 were observed have high of broad sense heritability for pod per plant, pod beak length, and time of flowering characters. The time of harvesting, seed per pod, pod per plant, and yield potential were had a medium level of broad sense heritability which means the genetic factor was expressed greatly from their parents than the environmental factors. The high heritability should be resulted a high genetic advance despite low genetic variation. The genetic variance and genetic advance have had a correlation to the heritability. If the heritability and genetic variance have had a high level, this character can be used as an observed trait in the next research. If the heritability has had a high level and the genetic variance has had a low or medium level, vice versa, the genetic advance would be had medium to low level. A high heritability and high genetic advance can be eased the selection and become efficient by evaluating the effect of environmental factors and additive gene action [8]. So, the heritability and genetic variance will be important to the genetic advance.

The new varieties have been created by using high heritability and high variance characters. This would be eased to improve any characters. The pod weight, pod length, and pod diameter was had a

low level of the broad sense heritability and the genetic variance coefficient. This can be caused by a high variance on the parent genotypes and the environmental factors greatly that affected plant expression. Hence, this characters was had no genetic advance on the further experiment. The seed per pod, pod per plant, and yield potential were had a medium-high level of broad sense heritability and low-medium level of genetic variance coefficient. Hence, those characters were had a high level of genetic advance.

Table 1. Broad sense heritability, genetic variance, and expected genetic advance each characters.

Characters	Parameters	Components	Result
Time of flowering	days	$H^2_{(BS)}$ (%)	67.44
		CGV (%)	8.35
		G	4.10
		EGA (%)	12.07
Time of harvest	days	$H^2_{(BS)}$ (%)	39.95
		CGV (%)	6.89
		G	3.57
		EGA (%)	7.67
Pod beak length	mm	$H^2_{(BS)}$ (%)	50.35
		CGV (%)	13.49
		G	1.17
		EGA (%)	16.86
Pod diameter	mm	$H^2_{(BS)}$ (%)	0.00
		CGV (%)	0.00
		G	0.00
		EGA (%)	0.00
Pod length	cm	$H^2_{(BS)}$ (%)	0.00
		CGV (%)	0.00
		G	0.00
		EGA (%)	0.00
Seed per pod	seed	$H^2_{(BS)}$ (%)	42.91
		CGV (%)	6.36
		G	0.52
		EGA (%)	7.34
Pod weight	g	$H^2_{(BS)}$ (%)	0.00
		CGV (%)	0.00
		G	0.00
		EGA (%)	0.00
Pod per plant	pod	$H^2_{(BS)}$ (%)	52.74
		CGV (%)	19.78
		G	16.26
		EGA (%)	25.29
100 seed weight	g	$H^2_{(BS)}$ (%)	10.41
		CGV (%)	4.82
		G	0.71
		EGA (%)	27.40
Yield potential per plant	g	$H^2_{(BS)}$ (%)	34.87
		CGV (%)	19.07
		G	71.01
		EGA (%)	19.83

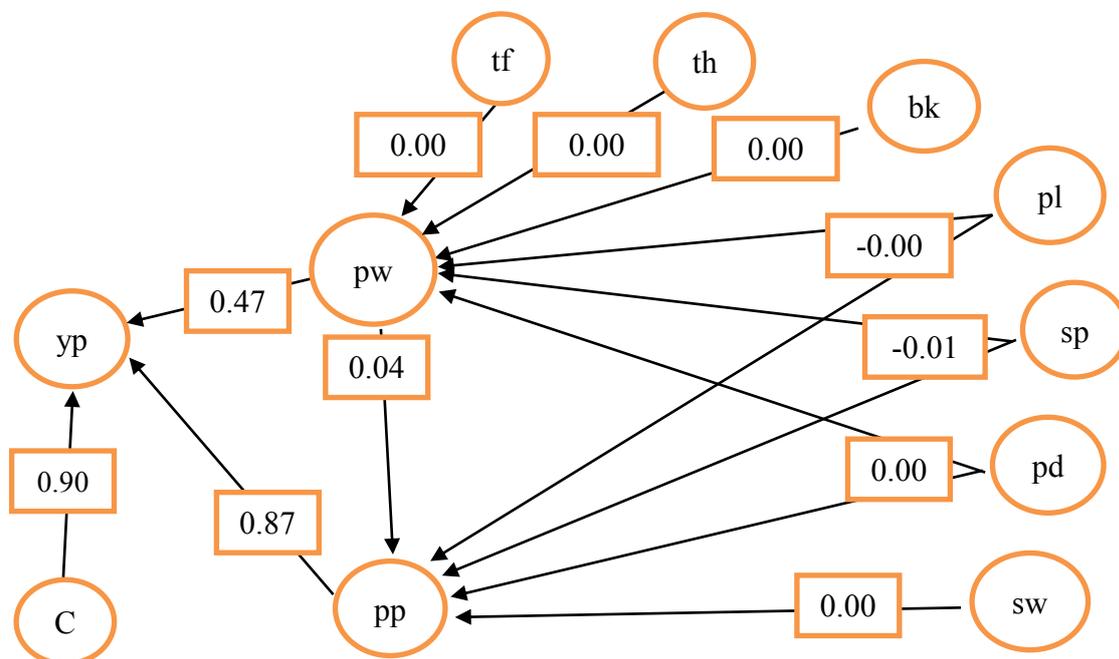
$H^2_{(BS)}$: broad sense heritability; CGV: coefficient of genetic variance; G: genetic advance by using 10% (1,76) selection intensity; and EGA: expected genetic advance

The high heritability and high genetic advance were affected by additive genes and easy to improve, but the high heritability and medium genetic advance can be being caused by the dominance and epistasis genes [9]. The additive effect can being assisted breeders to select the best genotypes for the self pollinated plant type. This result was indicated that a selection method using high heritability characters will be given a bigger chance of success for improving the characters, an effective selection strategy, and a higher chance to success [9]-[12]. The environments variance can be caused by the low heritability and low genetic advance [13].

Table 2. Correlation on each quantitative character on hybrid population of BCS-3 x BCS-7.

	th	bk	pd	pl	sp	pw	pp	sw	yp
tf	0.54**	0.09	0.20	0.14	0.18	0.24*	-0.19	0.17	-0.05
th	1	0.15	0.51**	0.18	0.17	0.45**	-0.22*	0.27*	-0.02
bk		1	0.06	-0.19	-0.08	-0.09	0.03	0.03	-0.04
pd			1	0.43**	0.19	0.78**	0.02	0.09	0.37**
pl				1	0.43**	0.79**	0.19	0.02	0.53**
sp					1	0.56**	0.14	-0.02	0.37**
pw						1	0.05	0.03	0.50**
pp							1	-0.09	0.88**
sw								1	-0.06**
yp									1

*: correlated on confidence level 95% probability; **: correlated on confidence level 99% probability



Quantitative characters (tf) time of flowering (days); (th) time of harvesting (days); (bk) pod beak length (mm); (pd) pod diameter (mm); (pl) pod length (cm); (sp) seed per pod; (pw) pod weight (g); (pp) pod per plant; (sw) 100 seed weight (g); (yp) potential yield; and (C) direct effect total

Figure 1. Path analysis on hybrid population of BCS-3 x BCS-7.

The parents were had lower variance than the F3 generation. The genetic variance on a population was based on the hybridization origin, generation, and genetic background [14]. The generation phase and segregation level will be being affected by the variance value. The parent genotypes were had higher pod diameter, pod length, and pod weight than the F3 generation (Table 4). The high variance in the parent genotypes can be caused by the temperature, humidity, and soil fertility factors [15], [16]. The variance in a population was formed by the environments, genetics, and interaction between environments and genetics. The variance of harvest time can be caused by plant determinacy, genetic variance, insects and diseases, and drought [17]. The early harvest on the french bean was resulted from the stress avoidance, especially on dwarf plants [18]. The genetic and environment contribution was had high enough to the variance. The variance on quantitative characters was caused by polygenic genes that had a small effect [19], collective work and not controlled by one gene [20].

Table 3. Spearman correlation between qualitative and quantitative characters on the hybridized population of BSC 3 x BCS 7.

	tf	th	bk	pd	pl
lr	0.14*	0.18**	-0.17*	0.00	-0.11
sc	0.09	0.10	0.14	0.07	0.01
pi	-0.11	-0.19**	0.24**	-0.06	0.02
dpc	0.26**	0.42**	-0.07	0.14	-0.05
bs	0.18**	0.35**	-0.10	0.22**	0.03
pt	0.09	0.14*	0.07	0.18**	0.18**
ps	0.13	0.22**	0.07	0.46**	0.25**
cs	-0.09	-0.07	-0.12	0.03	0.02
sb	0.02	0.08	-0.03	-0.01	0.03

	sp	pw	yp	pp	sw
lr	0.02	0.03	-0.08	-0.13	0.11
sc	0.20**	0.00	0.18*	0.23**	-0.36**
pi	0.01	-0.14*	0.03	0.11	-0.15*
dpc	0.03	0.06	-0.06	-0.09	0.12
bs	0.07	0.21**	0.00	-0.14*	0.18**
pt	-0.02	0.17**	0.07	-0.01	0.12
ps	0.03	0.44**	0.14*	-0.10	0.23**
cs	-0.16*	0.08	-0.13	-0.22**	0.47**
sb	0.07	-0.02	0.07	0.09	0.10

*: correlated on confidence level 95% probability; **: correlated on confidence level 99% probability. Qualitative characters: (lr) leaf rugosity; (sc) stem color; (pi) pod intensity; (dpc) degree of pod curvature; (bs) pod beak shape; (pt) pod texture; (ps) pod stringiness; (cs) seed color; and (sb) seed brilliance. Quantitative characters (tf) time of flowering (days); (th) time of harvesting (days); (bk) pod beak length (mm); (pd) pod diameter (mm); (pl) pod length (cm); (sp) seed per pod; (pw) pod weight (g); (pp) pod per plant; (sw) 100 seed weight (g); and (yp) yield potential

All economic characters were had a positive correlation to potential yield. It means all characters have had a relationship that affects the potential yield. The cluster total per plant, pod per plant, pod per cluster, pod length, pod weight, and time to harvest were had a positive correlation and significant to potential yield. Otherwise, the time to flower was had a negative correlation and significant [21]. The pod length, pod weight, plant height, leaf area, ovule total per plant, and seed per pod were correlated to the potential yield significantly [22]. The emergence percentage, plant height, leaf area,

primer branch total, secondary branch total, pod total, and pod diameter were correlated to the potential yield positively and significantly [9]. The pod weight, pod per plant, and seed per pod were had a positive correlation and significant to potential yield [24]. The adapted french bean genotypes would be had less percentage of flower fall until produce more pods, thus the french bean selection should be observed by using pod total per plant [25].

There are three options to interpret correlation number to path analysis. First, if the coefficient correlation between the cause factors and the effects has had a similar number with the direct effect, thus this character should be used effectively as selection criteria. Second, if the positive coefficient correlation has had a negative direct effect, thus the indirect effect should be caused the difference of correlation number and need to observe again. Third, if a negative coefficient correlation has had a positive direct effect, thus next selection model should be limited in order to the indirect effect was not disappeared [26].

Table 4. Spearman correlation between qualitative characters on hybridized population of BSC 3 x BCS 7.

	lr	sc	Pi	dpc	bs	pt	ps	cs	sb
lr	1	0.00	-0.15*	0.20**	0.19**	-0.13	0.08	-0.07	0.05
sc		1	0.01	0.21**	-0.04	-0.10	-0.08	-0.52**	0.15*
pi			1	-0.12	-0.10	-0.01	-0.01	-0.06	0.04
dpc				1	0.44**	0.02	0.11	-0.17*	0.15*
bs					1	0.11	0.21**	0.01	0.07
pt						1	0.21**	0.12	-0.02
ps							1	0.18**	0.04
cs								1	-0.04
sb									1

*: correlated on confidence level 95% probability; **: correlated on confidence level 99% probability. Qualitative characters: (lr) leaf rugosity; (sc) stem color; (pi) pod intensity; (dpc) degree of pod curvature; (bs) pod beak shape; (pt) pod texture; (ps) pod stringiness; (cs) seed color; and (sb) seed brilliance

All characters were analyzed by using path analysis. The pod weight and pod per plant were analyzed as the characters with highest direct effect to yield potential. These characters were showed a similar number of the correlation and path analysis. The pod weight correlation (0,50) was had similar to the direct effect (0,47). The pod total per plant correlation (0,88) was had a similar number to the direct effect (0,87). If the characters have the same number of correlation and path analysis, the characters should be becoming important traits for effective selection [26]. Hence, the pod weight and pod per plant were suggested as an important trait for next selection at this hybridized population.

The pod weight and pod per plants characters have been used for the development of french bean on this hybrid. The bigger pod weight and more pods per plant were suggested to create an early plant to harvest, bigger diameter, longer pod, and more seeds per pod. The pod per plants, pod weight, and pod length should be became the direct selection criteria [21]. The production character was had a positive direct effect on pod weight [23]. The yield component among french bean cultivars was associated with pod size and plant size [4]. French bean production might not necessary if we were using pod per plant. A few pods with bigger pod size has been became more important than more pod with small pod size. A big pod size was demanded with the market then followed with more pod per plant.

The most important to supply market requirements are represented by the high pod quality. French bean production has been limited by drought importantly followed with pest and disease [26]. Malformed, undeveloped, and curved pod, reduce of length, rough texture, poor quality on french bean pod, followed by increased concentrations of protein and zinc and decreased iron concentration in the

Pods have been affected by the drought [4]. Actually, these plants were grown in the lowland (250 m asl). The vine plant, especially french bean, has adapted to the highland (1,000 – 1,500 m asl). Thus, this resulted in poor pod quality for market quality on some genotypes. Then, the lowland french bean variety and higher marketable pod quality have been demanding to supply the marketable french bean.

Table 5. The average potential yield for each qualitative criteria.

Characters	Criteria	Total Plants	Yield potential Average (g)
Cotyledon color	Purple	53	353 ± 124
	Green	18	368 ± 103
	Pale green	7	344 ± 45
Hypocotyl color	Purple	60	354 ± 118
	Green	18	361 ± 106
Stem color* ²	Purple	50	347 ± 113
	Green	28	371 ± 119
Leaf rugosity	Weak	26	339 ± 112
	Strong	52	364 ± 113
Standard color	White	15	375 ± 93
	Pink	63	353 ± 119
Pod shape	Ovate	13	383 ± 119
	Heart shape	12	355 ± 121
	Round	51	345 ± 104
	8-Shape	2	488 ± 328
Pod curvature	Straight	25	320 ± 112
	Concave	18	374 ± 128
	S-shape	32	383 ± 107
	Convex	3	393 ± 41
Degree of pod curvature	Straight	12	345 ± 113
	Weak	60	359 ± 119
	Medium	6	358 ± 90
Pod beak shape ^{1,2}	Medium	15	414 ± 125
	Strong	63	430 ± 114
Pod stringiness* ¹	Weak	21	337 ± 118
	Medium	47	366 ± 111
	Strong	10	362 ± 132
Pod texture ¹	Smooth	2	374 ± 62
	Medium	65	370 ± 118
	Rough	11	278 ± 111
Pod color intensity ¹	Light	12	348 ± 89
	Medium	45	372 ± 120
	Dark	21	331 ± 117
Seed color ²	White	19	368 ± 110
	Purple	6	316 ± 118
	Black	53	359 ± 118
Seed brilliance	Matt	74	355 ± 117
	Shiny	4	359 ± 89

*correlated to yield potential; ¹correlated to pod weight; ²correlated to pod per plant. There were no significant difference on each criteria characters by using T-test with confidence level 95% probability

Some qualitative characters were shown correlation between each two main quantitative characters. This could be used as main qualitative characters to select the best lines. Unfortunately, the correlation was not much studied.

The qualitative characters were correlated with yield potential for each criteria (table 5). The result was analyzed by T-test with 95% confidence level. The green hypocotyl, green cotyledon, strong leaf rugosity, 8-shape pod, convex pod, weak pod curvature, strong pod beak, green stem, medium pod stringiness, smooth pod texture, white standard flower, white seed, shiny seed, and medium pod intensity were had higher potential yield than another criteria in the same character. Although no significant difference, this result should be observed in the different experiments.

The best nine genotypes were resulted the highest yield among another genotype. The F3-6, F3-39, F3-22, F3-24, F3-11, F3-82, F3-12, F3-13, and F3-80 were resulted the highest yield genotype. The F3-6 genotypes was yielded 720.2 g per plant (about 30 ton per hectare), while F3-80 was yielded 504.9 g per plant (about 21 ton per hectare). This should be taken in the next generations to create the new french bean that adapted on the lowland and highland.

4. Conclusions

The low and medium variance was had to the economical characters. The low and medium variance was not affected significantly by higher genetic gain than high heritability. The high criteria of broad sense heritability was resulted high genetic gain. Thus, selection should be used high heritability characters. The correlations were shown in all characters to potential yield except time to flowering, time to harvest, and pod beak length. Then, the correlation coefficient was used for path analysis. The pod weight and pod total per plant were showed higher correlation and direct effect than other characters. Thus, the pod weight and pod total per plant should be used as selection criteria to select high yielding french bean lines. Then, the stem color, pod beak shape, pod stringiness, pod texture, pod color intensity, and seed color character were had the correlation to pod weight, pod total per plant, and yield potential. Some quantitative and qualitative characters can be used for selecting the high yielding french bean

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