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Evaluation of Genetic Characteristics of Introduced Mungbean (*Vigna radiata*) Varieties Based on Agronomic Traits

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Abstract: Mungbean makes up a relatively large part of the daily needs of every Vietnamese family. However, mungbean yield in the Mekong Delta is still low, variety is one of the main factors affecting this problem. Therefore, the study of new varieties with high yield and adapting to different environmental conditions is extremely necessary. We evaluated the genetic characteristics such as productivity, growth time, and synchronous pod maturity of introduced mungbean based on agronomic traits (plant height at flowering, plant height at harvesting, number of internodes, number of branches, number of pods/plant, theoretical yield), thereby creating a database of genetic characteristics for further breeding programs. The results showed that all varieties had synchronous pod maturity and the mature pods were harvested up to two times after one planting season. The broad-sense heritability of studied traits including plant height at flowering and harvesting, number of internodes and branches, number of pods/plant, and theoretical yield varied from 15.57% to 85.71% in the first harvest and 68.45% to 89.58% in the second harvest. It can be seen that these traits were influenced by the environment. Hence, it is important to choose appropriate seasons to enhance the potential of the variety. Moreover, the correlation coefficient results showed a strong positive relationship between yield and the number of pods per plant, indicating that number of pods/plant is one of the important factors affecting mungbean yield. Based on important agronomic traits including the number of pods per plant, 1000 seed weight, growth time, and yield, two promising mungbean varieties were selected, which were VC 6494-986-S7 and VC 6518-50. This agronomic database of these introduced mungbean varieties will be used for mungbean breeding in Vietnam.

Keywords: agronomy; genetic parameters; *Vigna radiata*

1. Introduction

The mungbean [*Vigna radiata* (L.) Wilczek], a legume that was once only farmed in Asia, has expanded to countries all over the world due to its many uses. As a crucial crop for the economy, mungbean is usually cultivated intercropping with diverse cereals because it increases the nitrogen and carbon availability in the soil for subsequent crops [1]. Mungbean is prized for its great nutritional value because it contains 20 to 25% of protein [2]. Additionally, the essential amino acid composition of mungbean seems to be superior to soybean, kidney bean, and FAO/WHO reference protein [3]. However, the yield of mungbean in the Mekong Delta in general is still low, averaging 1 ton/ha. Many factors affect this plant's yield, such as cultivation techniques, varieties, climate, soil, etc. One of them is variety, which plays the most important role. Therefore, to achieve the goal of increasing mungbean yield, selecting varieties with high yield and resistance to some pests is necessary [4].

More genetic resources need to be investigated in order to increase genetic variety due to the poor genetic base of mungbean. In order to select the best parents for genetic improvement and further development of breeding programs, phenotypic diversity evaluation could be considered as an important part through characterizing morphological and agronomical traits [5]. Introduced variety has many important roles such as adding valuable genetic resources, increasing genetic diversity, and serving as a starting material to create new varieties [6]. Diversity in plant genetic resources provides the opportunity for plant breeders to develop new cultivars with desirable characteristics (high yield, large seed, pest and disease resistance, etc.). Hence, the evaluation of genetic characteristics is one of the primary goals of any crop improvement program [7]. Because of these reasons, this study: "**Evaluation of genetic characteristics of introduced mungbean (*Vigna radiata*) varieties based on agronomic traits**" was carried out. The aim of this study is for the genetic characteristics of 9 mungbean varieties to be evaluated based on agronomic traits. From there, 1 or 2 promising varieties could be selected for further research.

2. Materials and Methods

2.1. Materials

Table 1. List of 9 introduced mungbean varieties.

Code	Variety Name	Origin
1	VC 6512-6A	AVRDC, Thailand
2	VC 6570-157-7	AVRDC, Thailand
3	VC 6494-986-S7	AVRDC, Thailand
4	VC 6518-5	AVRDC, Thailand
5	VC 6495-32	AVRDC, Thailand
6	VC 6493-44-7	AVRDC, Thailand
7	VC 6469-12-3-4A	AVRDC, Thailand
8	VC 6469-12-4A	AVRDC, Thailand
9	Taichung (Control)	AVRDC, Taiwan

2.2. Apparatus, equipment and chemicals

Apparatus and equipment used in the study include plant pods, micropipettes, micropipette tips, microcentrifuge tubes, microcentrifuge machine, electrophoresis apparatus, microwave, PCR tubes, PCR Bio-Rad C1000 machine and BIORAD UV 2000 Gel Doc System, etc. Chemicals for DNA extraction include proteinase K, CTAB, β-mercaptoethanol, chloroform/isoamyl alcohol, RNAse, etc. DNA templates, distilled water, PCR Master Mix, agarose, TBE, safe view, loading dye were used for electrophoresis and PCR.

2.3. Methods

Nine varieties were grown in the net house with a completely randomized design (CRD), with 4 replications each. The criteria were based on the International Board for Plant Genetic Resources (IBPGR) [8].

2.4. Statistical analysis

The collected data were analyzed for variance (ANOVA) by Minitab 16 and for correlation coefficient by SPSS software. Besides, the Turkey test was used to test the mean difference between mungbean varieties at 1% and 5% significance levels. Processing raw data and calculating statistical characteristics such as mean, coefficient of variation, etc. using Microsoft Excel 2013 software.

3. Results

3.1. Morphological traits

Table 2. Summary table of morphological traits.

Code	Traits	Characteristic	Variety	Shannon index
1	**Hypocotyl color**	Purple	G2	0.48
		Green	G1, G3, G4, G5, G6, G7, G8, G9	
2	**Seed shape**	Oval	G1, G2, G5, G7	1.08
		Cylindrical	G3, G4, G6, G8	
		Other	G9	
3	**Pod color**	Black	G1, G3, G4, G5, G6, G7, G8, G9	0.2
		Brown	G2	
4	**Flower color**	Yellow	All	

Note: G1: VC 6512-6A, G2: VC 6570-157-7, G3: VC 6494-986-S7, G4: VC 6518-5, G5: VC 6495-32, G6: VC 6493-44-7, G7: VC 6469-12-3-4A, G8: VC 6469-12-4A, G9: Taichung.

3.2. Agronomic and yield traits

Table 3. Agronomic traits of 9 varieties in the first harvest.

Variety	X1	X2	X3	X4	X5	X6
VC 6512-6A	72.65 ^{ab}	77.43 ^{abcd}	6.62 ^{bc}	1.37 ^{c}	6.81 ^{a}	0.34 ^{bcd}
VC 6570-157-7	68.81 ^{b}	73.68 ^{d}	5.56 ^{c}	1.62 ^{bc}	6.62 ^{a}	0.30 ^{d}
VC 6494-986-S7	75.26 ^{ab}	86.48 ^{ab}	7.18 ^{ab}	1.56 ^{bc}	7.68 ^{a}	0.43 ^{ab}
VC 6518-5	74.01 ^{ab}	88.43 ^{a}	8.12 ^{a}	2.31 ^{ab}	7.81 ^{a}	0.45 ^{a}
VC 6495-32	65.21 ^{b}	72.53 ^{d}	6.93 ^{ab}	3 ^{a}	6.37 ^{a}	0.34 ^{bcd}
VC 6493-44-7	71.8 ^{ab}	83.75 ^{abcd}	7.81 ^{ab}	1.93 ^{bc}	6.93 ^{a}	0.36 ^{abcd}
VC 6469-12-3-4A	67.76 ^{b}	74.35 ^{cd}	7.31 ^{ab}	1.62 ^{bc}	6.18 ^{a}	0.31 ^{cd}
VC 6469-12-4A	66.84 ^{b}	75.79 ^{bcd}	7.43 ^{ab}	2 ^{bc}	6.12 ^{a}	0.32 ^{cd}
Taichung (Ctrl)	80.43 ^{a}	86.05 ^{abc}	6.62 ^{bc}	1.68 ^{bc}	7 ^{a}	0.41 ^{abc}
$\bar{X}$	71.42	79.84	7.07	1.9	6.84	0.36
CV%	12.3	12.39	15.92	52.85	36.53	37.33
Min	65.22	72.53	5.56	1.38	6.13	0.30
Max	80.43	88.43	8.13	3	7.81	0.45
V_p	76.64	97.17	1.25	1	6.2	0.018
V_g	54.93	72.99	1	0.86	1.46	0.013
V_e	21.71	24.18	0.25	0.14	4.74	0.005
PCV	12.25	12.34	15.87	52.67	36.41	37.2
GCV	10.37	10.7	14.18	48.76	31.84	31.67
h^2_b	71.67	75.11	79.86	85.71	76.46	72.48

Note: X1: Plant height at flowering in the first harvest (cm); X2: Plant height at harvesting in the first harvest (cm); X3: Number of internodes in the first harvest (internode); X4: Number of branches in the first harvest (branch); X5: Number of pods/plant in the first harvest (pod); X6: Theoretical yield in the first harvest (ton/ha). $\bar{X}$: Mean; CV%: Coefficient of variation; Vp: Phenotypic variance; Vg: Genotypic variance; Ve: Environmental variance; PCV: Phenotypic coefficient of variance; GCV: Genotypic coefficient of variance; h^2b: Heritability in broad sense. Means that do not share a letter are significantly different.

Table 4. Agronomic traits of 9 varieties in the second harvest.

Variety	X1	X2	X3	X4	X5	X6
VC 6512-6A	77.43 [abcd]	82.38 [abc]	10.25 [c]	2.06 [ab]	6.31 [ab]	0.28 [abc]
VC 6570-157-7	73.68 [d]	79.69 [c]	8.56 [d]	2.43 [a]	7.81 [a]	0.34 [ab]
VC 6494-986-S7	86.48 [ab]	93.4 [ab]	10.81 [bc]	2.25 [ab]	8.37 [a]	0.44 [a]
VC 6518-5	88.43 [a]	94.95 [a]	12.31 [a]	2.37 [a]	7.75 [a]	0.36 [ab]
VC 6495-32	72.53 [d]	78.37 [c]	10.5 [bc]	2 [ab]	3.93 [b]	0.15 [c]
VC 6493-44-7	83.75 [abcd]	89.93 [abc]	11.62 [ab]	1.62 [ab]	5.81 [ab]	0.24 [bc]
VC 6469-12-3-4A	74.35 [cd]	80.46 [bc]	10.68 [bc]	1.44 [ab]	5.87 [ab]	0.23 [bc]
VC 6469-12-4A	75.79 [bcd]	82.3 [abc]	10.43 [c]	1.5 [ab]	5.62 [ab]	0.23 [bc]
Taichung (Ctrl)	86.05 [abc]	94.32 [a]	10.37 [c]	1.18 [b]	6.75 [ab]	0.36 [ab]
$\bar{X}$	79.84	86.2	10.61	1.87	6.47	0.29
CV%	12.39	12.5	14.34	43.18	47.08	52.55
Min	72.53	78.38	8.56	1.19	3.94	0.15
Max	88.43	94.95	12.31	2.44	8.38	0.44
V_p	97.17	115.43	2.3	0.65	9.22	0.02
V_g	72.99	83.69	2.06	0.44	6.98	0.01
V_e	24.18	31.74	0.24	0.2	2.23	0.005
PCV	12.34	12.46	14.3	43.03	46.91	52.37
GCV	10.7	10.61	13.53	35.6	40.83	45.83
h^2_b	75.11	72.5	89.58	68.45	75.75	76.58

Note: X1: Plant height at flowering in the second harvest (cm); X2: Plant height at harvesting in the second harvest (cm); X3: Number of internodes in the second harvest (internode); X4: Number of branches in the second harvest (branch); X5: Number of pods/plant in the second harvest (pod); X6: Theoretical yield in the second harvest (ton/ha). $\bar{X}$: Mean; CV%: Coefficient of variation; Vp: Phenotypic variance; Vg: Genotypic variance; Ve: Environmental variance; PCV: Phenotypic coefficient of variance; GCV: Genotypic coefficient of variance; h^2b: Heritability in broad sense. Means that do not share a letter are significantly different.

Table 5. Growth time and 1000 seed weight of 9 varieties.

	Growth time at the first harvest (day after sowing)	Growth time at the first harvest (day after sowing)	1000 seed weight (g)
VC 6512-6A	54	79	66.77
VC 6570-157-7	53	78	77.53
VC 6494-986-S7	54	79	75.46
VC 6518-5	54	79.3	72.56
VC 6495-32	55	80.3	71.08
VC 6493-44-7	53	78	72.87
VC 6469-12-3-4A	54	79.3	67.61
VC 6469-12-4A	54	79	68.74
Taichung (Ctrl)	54	79	65.29
Mean	53.88	78.98	70.88
CV%	1.11	0.88	5.8

Note: CV%: Coefficient of variation.

3.3. Correlation coefficient

Table 6. Correlation coefficient.

	X1	X2	X3	X4	X5
X1	1				
X2	0.695 *	1			
X3	0.917 **	0.785 **	1		
X4	0.917 **	0.785 **	1.000 **	1	
X5	0.071 ns	0.335 ns	0.357 ns	0.357 ns	1

Note: X1: Theoretical yield in the first harvest (ton/ha); X2: Theoretical yield in the second harvest (ton/ha); X3: Number of pods/plant in the first harvest (pod); X4: Number of pods/plant in the second harvest (pod); X5: 1000 seed weight (g). (ns): Correlation is not significant; (*): Correlation is significant at 5%; (**): Correlation is significant at 1%.

4. Discussion

4.1. Morphological traits

There were 2 colors of hypocotyl which were green and purple. Out of the total of 9 observed cultivars, 1 cultivar with purple hypocotyl (11.1%) was VC 6570-157-7 and the remaining 8 cultivars had green hypocotyl (88.9%). Besides, the results recorded in 9 experimental varieties all had yellow flowers, the flower sizes of 9 varieties were the same.

There were 8 varieties that had mature pods with black color (VC 6512-6A, VC 6494-986-S7, VC 6518-5, VC 6495-32, VC 6493-44-7, VC 6469 -12-3-4A, VC 6469-12-4A, and Taichung) with the Shannon index was 0.2, the remaining variety had mature pod with brown color was VC 6570-157-7.

The seed shape trait had the Shannon index higher than the remaining trait, which was 1.08. Specifically, there were 4 varieties with an oval shape, 4 varieties with a cylindrical shape, and 1 variety with other shapes.

4.2. Agronomic and yield traits

The results of heritability analysis in the broad sense (h^2b) in Table 3 showed that the traits of plant height at flowering, plant height at harvesting, number of internodes, number of branches, number of pods/plant, and theoretical yield in the first harvest had a high heritability ranged from 71.67% to 85.71%. In Table 4, the results of heritability analysis in the broad sense (h^2b) showed that the trait number of internodes in the second harvest had the highest heritability (89.58%). The remaining traits had heritability in the broad sense ranging from 68.45% to 76.58%. Heritability is the ratio between genotypic variance to phenotypic variance, and a high heritability value suggests that genes contribute more to trait variance in the population [9]. From the results of the analysis, we can see that genes mainly contributed to the genetic characteristics of mungbean varieties but the varieties were also affected by the environment at both two times of harvest. Thus, it is necessary to pay attention to the selection of appropriate seasons and proper cultivation techniques to maximize the potential of the variety.

If based on the weight of 1000 seeds, the varieties VC 6570-157-7, VC 6494-986-S7, VC 6518-5, and VC 6493-44-7 were the varieties with outstanding advantages. If the variety would be selected for the purpose of shortening the growth time, the variety VC 6570-157-7 and VC 6493-44-7 were the two suitable varieties (Table 5). However, with the short growth time, the yield of the variety is not high. The yield of 9 varieties showed that VC 6494-986-S7 and VC 6518-5 were suitable choices (Table 3 and 4). Through the evaluation results, the varieties VC 6494-986-S7 and VC 6518-5 were two varieties with outstanding advantages. The varieties were selected despite having an average growth time, but this could be a suitable trait to ensure yield and increase crop intercropping.

According to Mondal, et al. [10], synchrony of pod maturity is measured based on the percentage of mature pods at first harvest, where: synchrony (>90% mature pods), partial synchrony (80-90% mature pods), and asynchrony (<80% mature pods). Hence, nine varieties had synchronous pod maturity.

4.3. Correlation coefficient

The results in Table 6 showed that the theoretical yield and the number of pods/plant in the first harvest had a strong positive relationship ($r = 0.917^{**}$). The correlation between the theoretical yield and the number of pods/plant in the second harvest also had a strong positive relationship ($r = 0.785^{**}$). It can be seen that the number of pods/plant is one of the important factors affecting mungbean yield, consistent with the evaluation of Thuy, et al. [11]. Whereas, a weak positive correlation was found between 1000 seed weight and theoretical yield in the first harvest ($r = 0.071^{ns}$) as well as theoretical yield in the second harvest ($r = 0.335^{ns}$).

5. Conclusions

The genetic characteristics of 9 new introduced mungbean varieties were evaluated in detail. Analysis results of morphology, agronomy and yield of 9 varieties showed that all varieties had synchronous pod maturity and had two harvests after one planting season, the first harvest had a growth time of about 53 to 55 days after sowing and the second harvest was from 70 to 80.3 days after sowing. The seed shape had a higher Shannon index (1.08) compared to the remaining traits. According to statistical analysis, two promising varieties, VC 6494-986-S7 and VC 6518-5, were selected.

The number of branches in the first harvest and the number of internodes in the second harvest had a higher heritability than the remaining traits, which was less influenced by the environment and mainly controlled by genes. The number of pods/plant had a positive correlation with yield, which were r = 0.917 in the first harvest and r = 0.785 in the second harvest. Therefore, this trait should also be noticed in mungbean yield improvement. The selected promising varieties should be used for the next studies and should be planted in different geographical areas to test the adaptability to the environment and the stability of the variety.

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