engineering proceedings

MDPI

Proceeding Paper

Evaluation of Genetic Characteristics of Introduced Mung Bean Varieties Based on Agronomic Traits †

My Thi Thao Tran * and Ngon Trong Truong

Department of Molecular Biology, Institute of Food and Biotechnology, Can Tho University, Can Tho 900000, Vietnam

* Correspondence: tranthaomy0208@gmail.com; Tel.: +84-84-258-5002

† Presented at the 4th International Electronic Conference on Applied Sciences, 27 October–10 November 2023; Available online: https://asec2023.sciforum.net/.

Abstract: Mung beans make up a relatively large part of the daily needs of every Vietnamese family. However, mung bean yield in the Mekong Delta is still low, and variety is one of the main factors affecting this problem. Therefore, the study of new varieties with a high yield and adaptability to different environmental conditions is extremely necessary. We evaluated genetic characteristics such as productivity and growth time of the introduced mung beans based on agronomic traits (plant height at flowering, plant height at harvesting, number of internodes, number of branches, number of pods plant^{-1}, and theoretical yield), thereby creating a database of genetic characteristics for further breeding programs. The results showed that the mature pods of all varieties 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^{-1}, and theoretical yield varied from 15.57% to 85.71% in the first harvest and from 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 mung bean variety. Moreover, the correlation coefficient results showed a strong positive relationship between yield and the number of pods per plant, indicating that the number of pods plant^{-1} is one of the important factors affecting mung bean yield. Based on important agronomic traits including the number of pods per plant, 1000 seeds' weight, growth time, and yield, two promising mung bean varieties were selected, which were VC 6494-986-S7 and VC 6518-50. Our results provided useful information for improving the yield of mung beans as well as contributing to the introduced mung bean breeding program in Vietnam.

Keywords: agronomy; genetic characteristics; *Vigna radiata*

Citation: Tran, M.T.T.; Truong, N.T. Evaluation of Genetic Characteristics of Introduced Mung Bean Varieties Based on Agronomic Traits. *Eng. Proc.* **2023**, *56*, 233. https://doi.org/10.3390/ASEC2023-16613

Academic Editor: Nunzio Cennamo

Published: 7 December 2023

1. Introduction

The mung bean [*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, mung bean is usually cultivated by intercropping with diverse cereals because it increases the nitrogen and carbon availability in the soil for subsequent crops [1]. Mung bean is prized for its great nutritional value because it contains between 20 and 25 percent protein [2]. Additionally, the essential amino acid composition of mung bean seems to be superior to soybean, kidney bean, and FAO/WHO reference protein [3]. However, the yield of mung beans 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 mung bean yield, selecting varieties with a 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 mung bean. 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 of 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]. The aim of this study is for the genetic characteristics of nine introduced mung bean varieties to be evaluated based on agronomic traits. From there, the database of these varieties could be used for the development of an introduced mung bean breeding program in Vietnam.

2. Materials and Methods

2.1. Materials

Nine varieties used in the study were presented in Table 1.

Table 1. List of nine introduced mung bean 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

Note: AVRDC: Asian Vegetable Research and Development Center.

2.2. Apparatus, Equipment and Chemicals

The apparatus and equipment used in the study included plant pods, a thermometer, fertilizers, and pesticides for mung bean cultivation.

2.3. Methods

Experimental Design

Nine varieties were grown in the net house using a completely randomized design (CRD), with four replications each. The criteria were based on the International Board for Plant Genetic Resources (IBPGR) [8], including: hypocotyl color (green, purple), recorded after 10 days of emergence; seed shape (oval, drum, others); pod color (brown, black); flower color (yellow); plant height at flowering measured from the ground to the top of the plant's growth, using 16 representative plants when 50% of plants had their first flower open; plant height at harvesting measured from the ground to the top of the plant's growth, using 16 representative plants when harvesting; number of internodes counted from the internode of the cotyledon to the last internode on the main stem (hypocotyl is considered as one internode) count at harvesting; number of branches, counting only pod-bearing branches; number of pods per plant, using the mean number (recorded as a whole number) of pods from 16 representative plants; growth time (number of days from planting to 95% of plants with ripe pods); 1000 seeds' weight (the weight of 1000 randomly selected seeds).

Theoretical yield is calculated by using Equation (1):

$$\frac{\text{seed weight per plant} \times \text{plants per ha}}{1,000,000} \tag{1}$$

where the weight of seeds plant^{-1} was calculated in grams at 12% moisture.

2.4. Statistical Analysis

The collected data were analyzed for variance (ANOVA) by Minitab 16 and for correlation coefficient by SPSS software v. 25. Additionally, the Turkey test was used to test the mean difference between mung bean varieties at 1% and 5% significance levels. Processing raw data and calculating statistical characteristics such as mean, coefficient of variation, etc. were obtained using Microsoft Excel 2013 software.

3. Results

3.1. Morphological Traits

The investigated morphological traits of nine varieties were noted in Table 2.

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

The results of the broad-sense heritability ($h^2{}_b$) 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^{-1}, and theoretical yield in the first harvest had a high heritability range from 71.67% to 85.71%.

Table 3. Agronomic traits of nine 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}
$\overline{X}$	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	4.74	0.013
V_e	21.71	24.18	0.25	0.14	1.46	0.005

Table 3. *Cont.*

Variety	X1	X2	X3	X4	X5	X6
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 first harvest (cm); X2: plant height at harvesting in first harvest (cm); X3: number of internodes in first harvest (internode); X4: number of branches in first harvest (branch); X5: number of pods plant^{-1} in first harvest (pod); X6: theoretical yield in first harvest (ton/ha). $\overline{X}$: Mean; CV%: coefficient of variation; V_p: phenotypic variance; V_g: genotypic variance; V_e: environmental variance; PCV: phenotypic coefficient of variance; GCV: genotypic coefficient of variance; h^2_b: broad-sense heritability. ^{a,b,c,d}: means that do not share a letter are significantly different.

In Table 4, the results of broad-sense heritability (h^2_b) showed that the trait number of internodes in the second harvest had the highest heritability (89.58%). The remaining traits had broad-sense heritability ranging from 68.45% to 76.58%.

Table 4. Descriptive statistics of nine 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}
$\overline{X}$	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	0.01
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 second harvest (cm); X2: plant height at harvesting in second harvest (cm); X3: number of internodes in second harvest (internode); X4: number of branches in second harvest (branch); X5: number of pods plant^{-1} in second harvest (pod); X6: theoretical yield in second harvest (ton/ha). $\overline{X}$: Mean; CV%: coefficient of variation; V_p: phenotypic variance; V_g: genotypic variance; V_e: environmental variance; PCV: phenotypic coefficient of variance; GCV: genotypic coefficient of variance; h^2_b: broad-sense heritability. ^{a,b,c,d}: Means that do not share a letter are significantly different.

The growth time and weight of 1000 seeds of nine varieties were recorded in Table 5.

Table 5. Growth time and the weight of 1000 seeds of nine varieties.

	Growth Time at the First Harvest (Day after Sowing)	Growth Time at the First Harvest (Day after Sowing)	1000 Seeds' 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

Table 5. *Cont.*

	Growth Time at the First Harvest (Day after Sowing)	Growth Time at the First Harvest (Day after Sowing)	1000 Seeds' Weight (g)
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

The results in Table 6 showed that the theoretical yield and the number of pods plant^{-1} in the first harvest had a strong positive relationship (r = 0.92 **). The correlation between the theoretical yield and the number of pods plant^{-1} in the second harvest also had a strong positive relationship (r = 0.79 **).

Table 6. Correlation coefficient results.

	X1	X2	X3	X4	X5
X1	1				
X2	0.69 *	1			
X3	0.92 **	0.79 **	1		
X4	0.92 **	0.79 **	1 **	1	
X5	0.07 ^{ns}	0.33 ^{ns}	0.36 ^{ns}	0.36 ^{ns}	1

Note: X1: Theoretical yield in first harvest (ton/ha); X2: theoretical yield in second harvest (ton/ha); X3: number of pods/plant in first harvest (pod); X4: number of pods plant^{-1} in t in 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 two colors of hypocotyl, which were green and purple. Out of the total of nine observed cultivars, one cultivar with purple hypocotyl (11.1%) was VC 6570-157-7 and the remaining eight cultivars had green hypocotyl (88.9%). In addition, the results recorded in nine experimental varieties all had yellow flowers, and the flower sizes of nine varieties were the same.

There were eight varieties that had mature pods with a 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) where the Shannon index was 0.2, and the remaining variety, VC 6570-157-7, had mature pods with a brown color.

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

4.2. Agronomic and Yield Traits

Heritability is the ratio between genotypic variance and phenotypic variance, and a high heritability value suggests that genes contribute more to trait variance in the population [9]. The estimation of high heritability in quantitative traits is useful for plant breeding. A high heritability means that environmental factors have a small effect on the traits being examined, thus breeding will be easier [10]. From the results of the analysis, we can see that genes mainly contributed to the genetic characteristics of mung bean varieties, but the varieties were also affected by the environment at both 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 varieties 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 nine varieties showed that VC 6494-986-S7 and VC 6518-5 were suitable choices (Tables 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.

4.3. Correlation Coefficient

It can be seen that the number of pods plant^{-1} is one of the important factors affecting mung bean yield, consistent with the evaluation of Thuy, et al. [11]. Whereas a weak positive correlation was found between 1000 seeds' weight and theoretical yield in the first harvest (r = 0.07 ^{ns}) as well as theoretical yield in the second harvest (r = 0.33 ^{ns}).

5. Conclusions

The genetic characteristics of nine introduced mung bean varieties were evaluated in detail. Analysis results of the morphology, agronomy and yield of nine varieties showed that all varieties 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 analyses, 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^{-1} had a positive correlation with yield, which was r = 0.92 in the first harvest and r = 0.79 in the second harvest. Therefore, this trait should also be noticed in mung bean yield improvement. We suggest the selected varieties should be planted in different geographical areas and seasons to test their adaptability to the environment as well as their stability.

Author Contributions: Conceptualization, N.T.T.; methodology, N.T.T.; resources, N.T.T.; formal analysis, M.T.T.T. and N.T.T.; investigation, M.T.T.T.; data curation, M.T.T.T.; writing—original draft preparation, M.T.T.T.; writing—review and editing, M.T.T.T.; supervision, N.T.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments: The authors are grateful to the Institute of Food and Biotechnology and the School of Agriculture, Can Tho University, for providing assistance with the materials and equipment used for the experiments.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Wang, L.; Wang, S.; Luo, G.; Zhang, J.; Chen, Y.; Chen, H.; Cheng, X. Evaluation of the Production Potential of Mung Bean Cultivar "Zhonglv 5". *Agronomy* **2022**, *12*, 707. [CrossRef]
2. Ganesan, K.; Xu, B. A critical review on phytochemical profile and health promoting effects of mung bean (*Vigna radiata*). *Food Sci. Hum. Wellness* **2018**, *7*, 11–33. [CrossRef]
3. Mubarak, A.E. Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. *Food Chem.* **2005**, *89*, 489–495. [CrossRef]

4. Chin, D.V.; Dung, L.V.; Thuong, V.H.K. Field trial of five promising mungbean varieties at Cho Moi district An Giang province Spring-Summer crop season 2004. *Can Tho Uni. J. Sci.* **2004**, *2*, 145–150.
5. Mohammad, G.A.; Mohammad, A.H.; Umakanta, S.; Mahabubul, A.A.K.M.; Ramakrishnan, M.N.; Rajib, R.; Sezai, E.; Kirill, S.G. Genetic Analyses of Mungbean [*Vigna radiata* (L.) Wilczek] Breeding Traits for Selecting Superior Genotype(s) Using Multivariate and Multi-Traits Indexing Approaches. *Plants* **2023**, *12*, 1984.
6. Hien, N.V. *Giao Trinh Chon Giong Cay Trong*; Vietnam Education Publishing House: Ha Noi, Vietnam, 2000.
7. Bhandari, H.R.; Bhanu, A.N.; Srivastava, K.; Singh, M.N.; Shreya; Hemantaranjan, A. Assessment of genetic diversity in crop plants—An overview. *Adv. Plants Agric. Res.* **2017**, *7*, 279–286.
8. International Board for Plant Genetic Resources (IBPGR). *Descriptors for Mung Bean*; International Board for Plant Genetic Resources: Rome, Italy, 1980; p. 18.
9. Jordan, W.S.; Christine, T.F.; Erica, E.G. CHAPTER 63—Genetics and Psychiatry. In *Massachusetts General Hospital Comprehensive Clinical Psychiatry*; Theodore, A.S., Jerrold, F.R., Maurizio, F., Joseph, B., Scott, L.R., Eds.; Mosby: St. Louis, MO, USA, 2008; pp. 853–883.
10. Thuy, T.T.T. Chon Tao Cac Dong Dau Xanh (*Vigna radiata* L.) Bang Dot Bien EMS Tren Hai Giong ĐX208 Va Taichung. Ph.D. Thesis, Can Tho University, Can Tho, Vietnam, 2017.
11. Thuy, T.T.T.; Ngon, T.T. Investigation of seed yield and pod maturity type in mutant mungbean lines at M5 generations. *Can Tho Uni. J. Sci.* **2016**, 218–225. [CrossRef]