RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
57 (6) 2414-2424, 2025
http://doi.org/10.54910/sabrao2025.57.6.15
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

EVALUATION OF YIELD POTENTIAL AND POD-SHATTERING RESISTANCE IN MUNG BEAN (*VIGNA RADIATA* L.)

S.H. SUTJAHJO, S.A. NISA, S. MARWIYAH*, and D. WIRNAS

Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, Bogor, Indonesia
*Corresponding author's email: marwiyahs@apps.ipb.ac.id
Email addresses of co-authors: surjonoagh@apps.ipb.ac.id, sefianaasmaunnisa2@gmail.com, desta@apps.ipb.ac.id

SUMMARY

Mung bean (*Vigna radiata* L.) is a susceptible legume species to pod shattering, posing a high risk of yield loss. This study aimed to evaluate the agronomic traits and pod-shattering resistance of IPB mung bean lines. The research, conducted at the IPB University, Bogor, Indonesia, involved the evaluation of 17 IPB mung bean lines and three comparison varieties. Observed traits included growth and yield components, as well as pod-shattering resistance under three conditions: the field, sun-drying (14 days), and oven drying (at 40 °C for seven days). Genetic variability among the lines was found for plant height, days to flowering, seed weight per pod, and pod length. All IPB mung bean lines were grouping into three main clusters based on cluster analysis. Growth traits and yield components were influenced by genetic factors to varying degrees, as reflected in their low, medium, and high heritability estimates. Most yield components exhibited low heritability, except for the seed weight per pod, which showed medium heritability. Lines F9-Lom2/129-34, F9-VR480B/V1-156, and F9-VR10/V1-49 demonstrated superior yield components and high productivity (2.19–2.37 t/ha). These three lines were classified as a resistant to highly resistant classification for pod shattering**.** The sun-drying method was most effective in revealing the variation in pod-shattering resistance among the tested lines. These findings confirm that genetic variation influences both yield potential and pod shattering resistance in mung bean lines, providing valuable insights for future breeding programs.

Keywords: Mung bean (*V. radiata* L.), determinate, pod-shattering resistance, selection, variance components, heritability, yield potential

Key findings: The research elucidates the yield potential and pod-shattering resistance of IPB mung bean (*V. radiata* L.) lines. Pod shattering on mung bean causes significant yield losses before and during harvest in tropical areas. It is valuable to have a simple method for observing pod shatter resistance without relying on laboratory tests.

Communicating Editor: Dr. Gwen Iris Descalsota-Empleo

Manuscript received: December 19, 2024; Accepted: October 30, 2025.

Citation: Sutjahjo SH, Nisa SA, Marwiyah S, Wirnas D (2025). Evaluation of yield potential and pod-shattering resistance in mung bean (*Vigna radiata* L.). *SABRAO J. Breed. Genet.* 57(6): 2414-2424. http://doi.org/10.54910/sabrao2025.57.6.15.

INTRODUCTION

Mung bean (*Vigna radiata* L.) is the third most important legume in Indonesia after soybeans and peanuts, for both production and consumption. Mung bean contain 59%–65% carbohydrates and 24%–28% protein by dry weight (Pataczek *et al*., 2018) and 20.97%–31.32% protein (Yi-Shen *et al*., 2018). To date, Indonesia still imports mung bean because national production is lower than the national demand. The Ministry of Agriculture (2022) reported a decline of 0.59 kg/capita per year mung bean availability from 2018 until 2022 (from 0.93 in 2018), with the sharpest decrease occurring in 2021–2022 at -43.05%. One of the causes of this low national production is the reduction in planting areas in central production regions, such as West Sumatra, Indonesia, where the cultivated area decreased by 38.6% over the past year from 7581.5 ha (BPS, 2023). Production possible increased through improvements in cultivation technology and the development of high-yielding varieties.

One of the challenges in mung bean cultivation is the asynchronous maturity, which leads to significant production losses. Asynchronous maturity increases labor requirements due to the need for multiple harvests (Putri *et al*., 2014). The reduction of labor demand for harvesting can be possible by growing the short harvesting period mung bean varieties (two or three times harvesting). Mung bean varieties with a short harvesting period offer several advantages, including reduced production inputs and yield losses (Qonita *et al*., 2022). Mung bean lines resistant to pod shattering have the potential to achieve higher productivity by minimizing pod shattering.

Mung bean naturally tend to shatter their pods if left in the field too long while awaiting the ripening of other pods, resulting in yield loss. Pod shattering is influenced by both genetic and environmental factors, such as temperatures (Adeyeye *et al*., 2014; Vairam *et al*., 2017) and humidity (Zhang *et al*., 2018). During the mung bean life cycle, early-maturing pods are prone to pod shattering if a delay in harvest occurs, further increasing yield loss. Planting mung bean lines that are resistant to pod shattering can reduce the risk of yield loss even with delayed harvesting. This study aims to evaluate pod-shattering resistance and yield-related traits of mung bean lines generated from crossing.

MATERIALS AND METHODS

Genetic material

This research progressed from September 2023 to January 2024 at the IPB University Field Experimental Station. The genetic material comprised 17 IPB mung bean lines. These are F6-Lom2/129-125, F7-Lom2/V2-6, F7-VR422H/129-23, F7-VR480B-213, F8-Lom2/129-22, F8-Lom2/129-42, F8-Lom2/129-28, F8-VR10/V1-10, F8-VR422H/129-1, F9-Lom2/129-2, F9-Lom2/129-34, F9-Lom2/129-49, F9-VR10/V1-6, F9-VR10/V1-29, F9-VR10/V1-49, F9-VR480B/V1-82, and F9-VR480B/V1-156 IPB. The study also used three national check cultivars (Vima 1, Vima 4, and Vima 5). All recommended agronomic and crop protection practices took place to ensure optimal crop growth.

Experimental design

The experimental design employed was a randomized complete block design (RCBD) with genotype as a single factor, consisting of 17 IPB mung bean genotypes and three check varieties. The experiment consisted of three replications, resulting in 60 experimental units. Each experimental unit measured 3 m × 2 m, with a planting space of 40 cm × 15 cm, resulting in 100 planting holes per experimental unit. From each experimental unit, 10% of the population was sampled, equivalent to 10 sample plants, for agronomic character observations.

Experimental observations

Agronomic character observations commenced at the first harvest (when at least 80% of pods were black on each plant) and the second harvest (when plants had reached the final harvest stage or senescence). Pod-shattering observations proceeded under three different conditions: in the field, sun-dried, and oven-dried. Field pod-shattering resistance observations continued when plants were 10–12 weeks after planting (WAP). Oven-dried pod-shattering observations progressed on 25 pods from non-sample plants, which underwent placement in an oven at 40 °C for seven days. On the seventh day, the number of shattered or cracked pods entailed counting. Sun-dried pod-shattering resistance observations succeeded on 100 pods from non-sample plants over a 14-day sun-drying period. The results, expressed as percentages, used the following formula:

$$Pod\ shattering\ percentage\ (\%) = \left(\frac{Number\ of\ shattered\ pods}{Total\ number\ of\ pods}\right) \times 100$$

The assessment scale followed the method adopted by the International Institute of Tropical Agriculture (IITA, 1986), as follows: 0% shattered pods (highly resistant to pod shattering), < 25% shattered pods (resistant to pod shattering), 25%–50% shattered pods (susceptible to pod shattering), and > 51% shattered pods (highly susceptible to pod shattering).

Statistical analysis

Statistical analysis used the analysis of variance (ANOVA), followed by Dunnett's t-test. Further analyses included estimation of broad-sense heritability, correlation analysis of quantitative traits, and cluster analysis, using the Statistical Analysis System (SAS).

RESULTS AND DISCUSSION

General research conditions

The genetic material comprising 17 IPB mung bean genotypes, was cultivated during the experimental period, under environmental condition characterized by an average rainfall was 437.94 mm, average monthly temperature was 26.95 °C, average humidity was 79.22%, and average sunshine duration was 6.39 hours (BMKG, 2024). Crop conditions during the study sustained exceptionally high rainfall in November 2023, reaching 1,068 mm, which caused crop lodging. The high rainfall in November (Table 1) coincided with the plants entering their generative phase, which included flowering, pod formation, and pod maturation. Mung bean growth and development typically achieve effects from variables such as temperature, light, and moisture (Amitrano *et al*., 2020). High rainfall can reduce both yield and seed quality (Lestari *et al.,* 2019) and could lead to flower abscission (Tania *et al*., 2023).

IPB mung bean performance

Analysis of variance was used to assess the effect of genotype on observed traits. Based on the recapitulation of ANOVA (Table 2), genotype significantly affected plant height at the 5% level and had a highly significant effect at the 1% level on flowering time, seed weight per pod, pod length, seed number per pod, and sun-drying pod-shattering percentage. Traits showing no significant differences include the first harvest time, the second harvest time, pod count, pod weight, seed weight per plant, and field pod-shattering percentage. A considerable effect of genotype indicates variability due to genetic differences, while a non-significant impact indicates genetic similarity for the related trait. Such similarities can arise due to selection. This research population (F6-F9) attained selection for early harvest, short harvest period, and high yield, as previously studied by Maulida *et al*. (2022), Rospita (2023), Willem (2023), and Sefiana (2024).

Table 3 presents the performance of quantitative traits, including plant height, days of flowering, days of first harvest, and days of second harvest, for 17 mung bean lines and three control varieties. Plant height, measured at the second harvest, ranged from 48.30 to 77.33 cm, with an average of 64.66 cm. Based on Dunnett's t-tests, a significant difference in the plant height appeared among the evaluated genotypes. Genotype F7-VR480B-213 was notably shorter than the three control

Table 1. Average temperature, humidity, rainfall, and sunshine duration data for Bogor Regency from September 2023 to January 2024.

Year	Month	Temperature (°C)	Humidity (%)	Rainfall (mm/month)	Sunshine duration (hour/day)
2023	September	26.74	71.96	62.20	7.98
	October	27.74	74.07	102.10	7.71
	November	26.85	83.97	1068.00	6.10
	December	27.18	80.00	563.60	6.58
2024	January	26.26	86.10	393.80	3.59
Average		26.95	79.22	437.94	6.39

Source: Badan Meteorologi, Klimatologi, dan Geofisika (2024).

Table 2. Mean square and F-value of characteristics of mung bean lines and check varieties.

Characters	Mean Square	CV (%)
Plant height	200.73*	15.39
Days of flowering	3.07**	3.03
Days of first harvesting	6.51 ns	3.92
Days of second harvesting	29.07 ns	2.24
Number of pods	7.41 ns	19.31
Pod weight	3.19 ns	20.36
Seed weight per plant	1.64 ns	17.56
Seed weight per pod	0.01**	9.17
Pod length	1.37**	6.86
Number of seeds per pod	2.72**	3.16
Productivity	0.03 ns	17.58

**= significant at p ≤ 0.01; *= significant at p ≤ 0.05; ns= not significant; and T= root transformation results.

Table 3. Mean plant height, days of flowering, and harvesting of mung bean lines.

Genotypes	Plant height (cm)	Days of flowering (DAS)	Days of first harvesting (DAS)	Days of second harvesting (DAS)
F6-Lom2/129-125	70.88	37.00	66.33	95.00
F7-Lom2/V2-6	72.04	37.00	64.67	91.00
F7-VR422H/129-23	65.98	36.00	67.00	95.33
F7-VR480B-213	48.30[b]	36.00	64.00	93.00
F8-Lom2/129-22	55.38	38.00	68.33	93.33
F8-Lom2/129-28	74.69	38.67[a]	66.67	92.67
F8-Lom2/129-42	75.87	38.50	65.67	93.33
F8-VR10/V1-10	65.44	35.33	63.67	90.67
F8-VR422H/129-1	59.31	36.33	66.33	90.67
F9-Lom2/129-2	61.30	38.00	66.67	94.67
F9-Lom2/129-34	66.55	36.33	65.67	91.67
F9-Lom2/129-49	62.97	36.67	64.00	93.33
F9-VR10/V1-6	69.97	37.67	65.00	91.33
F9-VR10/V1-29	58.36	35.50	63.33	91.67
F9-VR10/V1-49	60.21	35.33	63.33	89.67
F9-VR480B/V1-82	60.16	37.67	66.00	80.67
F9-VR480B/V1-156	73.75	36.00	66.33	94.33
Vima 1	53.67	35.67	64.67	92.33
Vima 4	77.33	36.67	66.67	92.33
Vima 5	55.76	36.00	64.00	94.33

[a] = significantly different from Vima 1, [b] = significantly different from Vima 4, [c] = significantly different from Vima 5 based on t-Dunnett's t-test at the 5% level, DAS = days after sowing.

varieties, while F8-Lom2/129-42 was the tallest (75.87 cm), though still shorter than the Vima 4. According to Balitkabi (2018), the typical plant heights for Vima 1, Vima 4, and Vima 5 are 53, 76.6, and 64.4 cm, respectively. Most of the tested genotypes had plant heights similar to the control varieties. This signifies that the tested genotypes had plant heights conforming to the standards of released commercial mung bean varieties (Rospita, 2023). A shorter plant habit is advantageous for simultaneous harvesting, as it helps reduce continuous growth and increases lodging resistance (Marwiyah *et al*., 2021). Plant height sustains genetic control (high heritability), as reported by Maulida *et al*. (2022) and Sutjahjo *et al*. (2022).

The recording of flowering time ensued when at least one fully bloomed flower appeared on each plant within a genotype. The flowering time ranged from 35.33 to 38.67 days. The earliest flowering genotypes were F8-VR10/V1-10 and F9-VR10/V1-49, while the latest flowering genotype was F8-Lom2/129-28. Previous genetic research has shown that flowering time obtains control from a few genes, namely, two duplicate genes in a homozygous recessive state (Wani and Kozgar, 2016). Compared with the descriptions of the three comparison varieties (Vima 1, Vima 4, and Vima 5 as national varieties), the flowering times in this study were 1–3 days later. These delays appear to be related to environmental factors (Table 1), from October (vegetative phase) to November (generative phase), which included a decrease in temperature and sunlight duration and an increase in air humidity and rainfall. In other words, the study period coincided with the onset of the rainy season, with peak rainfall in November. These results align with those of Marwiyah *et al*. (2021), who reported delays in mung bean flowering and harvest times are longer in the rainy season than in the dry season. Flower shading is also higher during this period, leading to lower yields.

The harvest of mung bean proceeded in two stages. The first harvest time emerged when 80% of the pods on mung bean plants had turned black in each genotype population. The earliest genotypes harvested were F9-VR10/V1-29 and F9-VR10/V1-49, with a first harvest time of 63.33 days. Genotype F8-Lom2/129-22 had the longest first harvest time (68.33 days) and was significantly different from the Vima 1. However, the first harvest time did not differ significantly across most genotypes, as it did not vary much from the control varieties. The second harvest time took place when the mung bean plants reached their final harvest. This stage, also known as senescence, is evident with 50% defoliation, and the plants are no longer producing economically viable pods (Willem, 2023). The earliest senescence occurred in genotype F9-VR480B/V1-82 at 80.67 days, while the latest was in genotype F7-VR422H/129-23 at 95.33 days. Genotype F9-VR480B/V1-82 could obtain a classification of a short-duration mung bean genotype compared with the three control varieties. Genotype F8-Lom2/129-22, with an early second harvest time, was significantly different from Vima 1, indicating its potential as a short harvest-period genotype suitable for catch cropping (Rehman *et al.,* 2019; Marwiyah *et al*., 2021).

Table 4 shows the number of pods per plant ranged from 10.00 to 15.33. Genotype F9-VR10/V1-6 had the highest average number of pods, while the genotypes F8-VR422H/129-1 and F9-VR480B/V1-82 had the fewest. According to Sutjahjo *et al*. (2022), the number of pods of mung bean has a positive correlation with the length of the generative phase, days of harvest, and plant height, but a negative association with days of flowering.

The average pod weight per plant in this study ranged from 6.61 to 10.81 g (Table 4). Genotype F9-VR480B/V1-82 had the lightest pod weight, while F9-VR480B/V1-156 had the heaviest. Flowers that grow earlier have more pods than those that grow later, which also entails influences from leaf chlorophyll and nitrogen levels (Mohammed and Abdulkafoor, 2018). Planting mung bean in an environment with high rainfall intensity affects the pod set and pod-filling process (Hussain *et al*., 2022).

The mung bean genotypes exhibited varying seed weights per plant, ranging from 4.05 to 7.11 g (Table 4). Genotype F9-Lom2/129-49 had the lowest seed weight per

Table 4. Mean of yield and yield component traits of mung bean lines.

Genotypes	NP/ plant (g)	PW/plant (g)	SW/plant (g)	PL (cm)	WS/pod (g)	Prod (t/ha)
F6-Lom2/129-125	13.3	8.06	5.50	9.67	0.61	1.83
F7-Lom2/V2-6	11.0	8.00	5.65	10.18	0.73	1.89
F7-VR422H/129-23	12.3	8.53	5.65	9.67	0.70	1.88
F7-VR480B-213	12.3	8.46	5.90	10.15	0.71	1.97
F8-Lom2/129-22	12.7	9.37	5.94	10.47	0.80	1.98
F8-Lom2/129-28	12.7	8.30	5.85	9.80	0.68	1.95
F8-Lom2/129-42	12.3	8.00	5.70	9.69	0.66	1.90
F8-VR10/V1-10	12.3	8.35	5.96	1 10.07	0.70	1.99
F8-VR422H/129-1	10.0	7.25	5.17	10.04	0.68	1.72
F9-Lom2/129-2	10.3	7.51	4.70	11.31 [b]	0.76	1.57
F9-Lom2/129-34	14.3	10.19	6.59	11.84 [bc]	0.82	2.19
F9-Lom2/129-49	15.0	8.31	4.05	9.88	0.63	1.93
F9-VR10/V1-6	15.3	8.56	5.90	10.78	0.68	1.97
F9-VR10/V1-29	10.3	8.29	5.90	10.11	0.78	1.97
F9-VR10/V1-49	12.7	9.42	6.68	10.57	0.78	2.23
F9-VR480B/V1-82	10.0	6.61	4.69	9.24	0.68	1.56
F9-VR480B/V1-156	12.7	10.81	7.11	11.37 [b]	0.86[bc]	2.37
Vima 1	11.7	9.55	6.28	10.73	0.74	2.09
Vima 4	11.0	7.53	5.10	9.49	0.70	1.70
Vima 5	11.3	7.26	4.88	10.02	0.66	1.63

NP = number of pods, PW = pod weight, SW = seed weight, PL = pod length, WS = weight of seed per pod, Prod = productivity, [a] = significantly different from Vima 1, [b] = significantly different from Vima 4, [c] = significantly different from Vima 5 based on Dunnett's t-test at the 5% level.

plant, while F9-VR480B/V1-156 had the highest. Seed weight per plant can predict yield in tons per hectare. Previous research reported by Gogoi *et al.* (2021) showed that seed weight per plant had a significant positive correlation with mung bean yield. The predicted productivity in this study ranged from 1.56 to 2.37 tons per hectare (Table 4). In 2023, the national productivity of mung bean reached 1.14 tons per hectare (Dirjen Tanaman Pangan, 2023). According to the descriptions of mung bean varieties, Vima 1, Vima 4, and Vima 5 have average yields of 1.38, 1.73, and 1.84 tons per hectare, respectively (DPKP, 2023). This indicates the predicted productivity in this study was equivalent to the control varieties. The productivity of Vima 1 in this study was higher than the yield potential described for Vima 1, which is only 1.76 tons per hectare, because Vima 1 is more resistant to powdery mildew than Vima 4 and Vima 5. Mung bean yields are also at risk of pod shattering and pre-harvest sprouting; 60%–70% yield losses resulted from these factors (Parker *et al.,* 2021; Mogali *et al*., 2023).

According to the variety description, the yield potential of Vima 4 and Vima 5 can reach 2.20 tons per hectare and 2.34 tons per hectare, but this study only produced 1.70 and 1.63 tons per hectare, respectively. This is due to fluctuations in rainfall during the pod-filling phase before the second harvest, causing suboptimal plant metabolism. Suboptimal sunlight intensity can affect the photosynthesis capacity. A short photosynthesis period influences the accumulation of photosynthates from the source to the sink (seeds), which can lead to a decrease in seed weight (Waniale *et al*., 2014).

Table 4 also presents the results of observations on pod length and seed weight per pod. The pod length of the mung bean genotypes observed ranged from 9.24 to 11.84 cm. Three mung bean genotypes had significantly different pod lengths compared with the control varieties. The genotypes F9-Lom2/129-2 and F9-VR480B/V1-156 were significantly longer than the Vima 4. Genotype F9-Lom2/129-34 had the longest pod length among the tested genotypes, at 11.84 cm, and it was remarkably different from both Vima 4 and Vima 5. The seed weight per pod in this study ranged from 0.61 to 0.86 g. The genotype F6-Lom2/129-125 had the lowest seed weight per pod. The genotype F9-VR480B/V1-156 had a significantly higher seed weight per pod than the control varieties Vima 4 and Vima 5. Gogoi *et al*. (2021) stated a significant and positive correlation between pod length and yield.

Pod-shattering resistance of IPB mung bean lines

Pod shattering is an undesirable trait in mung bean, as it can negatively affect yield. Pod shattering refers to the explosive dehiscence of the pod at the maturation phase, which usually disperses seeds (Parker *et al*., 2021). An emergence of pod shattering before harvest causes significant yield loss (Willem, 2023); developing pod-shattering resistance is an essential way to maintain maximum mung bean production. In this study, pod-shattering resistance succeeded in testing under three different conditions: in the field, sun-drying, and oven drying.

The results of field pod-shattering observations showed all genotypes were highly resistant or resistant to pod shattering (Table 5). The findings are similar to the oven-dried pod shattering. Oven testing at 40 °C showed that eight lines experienced pod shattering. Seven genotypes were highly resistant, and four genotypes were resistant to pod shattering in field and oven observations. These two conditions differ from sun-drying in triggering pod shattering. Sun-drying was more effective in discriminating pod-shattering responses among genotypes. Seven genotypes changed categories from highly resistant/resistant to susceptible, and 13 genotypes remained stable as highly resistant/resistant. Based on this result, the 13 genotypes were resistant to pod shattering in identical environments (moderate humidity and rainy weather) and across two harvest periods. The sun-drying method is favorable for evaluating pod shattering under high humidity and rainy conditions during the pod-maturing phase compared with observations in the field and oven conditions.

Table 5. Mean percentage of field pod shattering, percentage of sun-dried pod shattering, and percentage of oven-dried pod shattering of mung bean lines.

Genotypes	PFPS (%)	Criteria	PSPS (%)	Criteria	POPS (%)	Criteria
F6-Lom2/129-125	0.5	R	68.0	HS	9.3	R
F7-Lom2/V2-6	0.0	HR	58.0	HS	8.0	R
F7-VR422H/129-23	0.0	HR	10.7	R	0.0	HR
F7-VR480B-213	0.2	R	25.0	S	0.0	HR
F8-Lom2/129-22	0.8	R	13.7	R	2.7	R
F8-Lom2/129-28	0.0	HR	9.7	R	0.0	HR
F8-Lom2/129-42	0.3	R	7.7	R	0.0	HR
F8-VR10/V1-10	0.2	R	48.7	S	4.0	R
F8-VR422H/129-1	0.0	HR	10.3	R	0.0	HR
F9-Lom2/129-2	0.3	R	16.3	R	2.7	R
F9-Lom2/129-34	0.2	R	6.7	R	4.0	R
F9-Lom2/129-49	0.0	HR	16.0	R	0.0	HR
F9-VR10/V1-6	0.0	HR	45.7	S	5.3	R
F9-VR10/V1-29	0.0	HR	38.3	S	0.0	HR
F9-VR10/V1-49	0.0	HR	3.0	R	0.0	HR
F9-VR480B/V1-82	0.2	R	16.7	R	0.0	HR
F9-VR480B/V1-156	0.0	HR	22.3	R	1.3	R
Vima 1	0.5	R	32.0	S	0.0	HR
Vima 4	0.5	R	33.7	S	4.0	R
Vima 5	0.0	HR	29.0	S	6.7	R

PFPS = percentage of field pod shattering, PSPS = percentage of sun-dried pod shattering, POPS = percentage of oven-dried pod shattering, HR = highly resistant, R = resistant, S = susceptible, and HS = highly susceptible.

Table 6. Estimated variance components and heritability values of yield and yield component traits on mung bean lines.

Characters	σ^2_p	σ^2_e	σ^2_g	h^2_{bs} (%)	h^2_{bs} criteria
Plant height	132.40	98.23	34.17	25.81	Moderate
Days of flowering	1.85	1.23	0.61	33.14	Moderate
Days of first harvesting	6.56	6.59	0.00	0.00	Low
Days of second harvesting	12.52	4.24	8.28	66.10	High
Number of pods	6.19	5.58	0.61	9.85	Low
Pod weight	3.02	2.94	0.08	2.75	Low
Seed weight per plant	1.46	1.37	0.09	6.21	Low
Seed weight per pod	0.01	0.00	0.00	39.44	Moderate
Pod length	0.79	0.50	0.29	36.99	Moderate

σ^2_p = phenotypic variance, σ^2_e= environmental variance, σ^2_g = genetic variance, and h^2_{bs} = broad-sense heritability

According to Krisnawati and Adie (2017) and Krisnawati *et al*. (2022), pod shattering varies due to genetic factors, low humidity, and harvest delays. Parker *et al*. (2021) confirmed that low humidity is an environmental factor that greatly contributes to legume pod shattering. In this study, the air humidity was 79.22%, which is in the moderate category; thus, the pod-shattering test in the field was not enough to trigger different genotype responses.

In this study, field and oven testing showed the tested lines were resistant to pod shattering. Sun-drying testing proved more effective in showing the variability of pod shattering among the lines. The sun-dried pod-shattering approach is much better for pod-shattering evaluation, especially under high humidity and rainy seasons during the generative phase, than the observations in the field and oven conditions.

Variance components and heritability

Heritability is the ratio between genetic variance and the total phenotypic variance of a particular trait. Both genetic and environmental factors play a role in the final appearance, or phenotype, of the observed traits. Based on the analysis of variance component estimates and broad-sense heritability (Table 6), heritability ranged from 0% to 83.65%. Two traits exhibited high broad-sense heritability values, including days to second harvesting and sun-drying pod-shattering percentage. Degefa *et al*. (2014), Dutt *et al*. (2020), and Afroz *et al*. (2022) highlighted the potential presence of additive genes, which is promising for selection when heritability is high. According to Shintawati *et al*. (2022), high heritability results from a more dominant genetic influence, making it a reliable basis for selection in subsequent generations.

All yield components showed low heritability (Table 6). This result indicates these traits mostly acquired influences from environmental factors, meaning the passing down of traits may not be reliably possible to future generations. Priyanto *et al*. (2018) also noted when the phenotype received a heavy alteration from the environment, traits may change when grown in different environments or seasons. Rospita (2023) noted low heritability indicates the phenotype has high environmental influence. Regarding its use in plant breeding, Wirnas *et al*. (2022) reviewed the heritability and correlation between traits related to selection decisions and estimation of plant ideotype. Mukhlisin *et al*. (2025) suggested not using traits with low heritability as selection criteria.

High heritability values in traits, such as the second harvest time, seed number per pod, and sun-drying pod-shattering percentage, suggest that these traits incurred primary influences from genetic factors and can be a reliable selection in breeding programs. Conversely, traits with low heritability, such as the first harvest time and pod weight, gained more effects from environmental conditions and may not have consistency in passing down through generations.

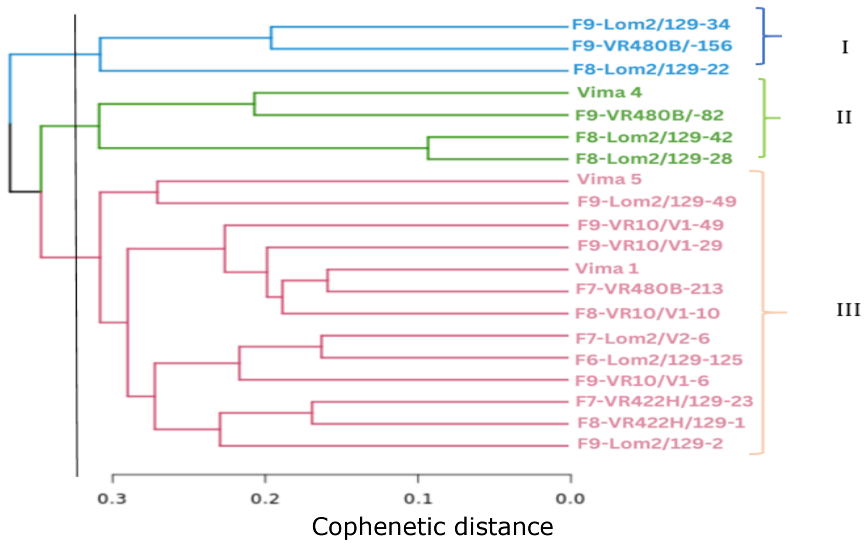

Figure 1. Dendrogram of 20 mung bean lines based on quantitative and qualitative traits.

Dendrogram

Cluster analysis took place based on cophenetic distances between the traits tested. The results of the cluster analysis are in the form of a diagram called a dendrogram. This analysis shows the dissimilarity between the traits of the mung bean genotypes tested. The dissimilarity value obtained in Figure 1 is 0.3, or 30%, indicating that the similarity of traits between the tested genotypes is 70%. Three clusters resulted, i.e., clusters I, II, and III. The clusters formed in the dendrogram indicate the presence of phenotypic variability among genotypes (Hamidah *et al*., 2024; Suparno *et al*., 2024).

The genotypes in Cluster I (F8-Lom2/129-22, F9-Lom2/129-34, and F9-VR480B/V1-156) exhibited the best characteristics regarding pod length and the seed number per pod. Cluster II (F8-Lom2/129-28, F8-Lom2/129-42, F9-VR480B/V1-82, and Vima 4) shared similarities in seed glossiness traits. Cluster III (F6-Lom2/129-125, F7-Lom2/V2-6, F7-VR422H/129-23, F7-VR480B-213, F8-VR10/V1-10, F8-VR422H/129-1, F9-Lom2/129-2, F9-Lom2/129-49, F9-VR10/V1-6, F9-VR10/V1-29, and F9-VR10/V1-49) displayed similarities in early flowering time and the first harvest time, suggesting potential for short-duration growth. Early maturity classification falls under the synchronized harvesting (Marwiyah *et al*., 2021). The advantages of each cluster can serve as a basis for selecting parental lines for crossing. Crosses between clusters may result in superior traits.

CONCLUSIONS

Mung bean genotypes affect the variability of plant height, days to flowering, seed weight per pod, and pod length. The genotypes underwent clustering into three main groups based on the dendrogram. All traits bore influences from genetic factors to varying degrees, as indicated by low, medium, and high heritability estimates. All yield component characters have low heritability, except the seed weight per pod (which has medium heritability). Lines F9-Lom2/129-34, F9-VR480B/V1-156, and F9-VR10/V1-49, selected from line crossbreeding, have high yield component characters and high productivity (2.19–2.37 t/ha). These three genotypes are resistant or very resistant to pod shattering. The sun-drying pod-shattering method is favorable for recommendation, as it was more effective in showing the level of pod-shattering variation among the tested lines.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Indonesian Ministry of Research, Technology, and Higher Education for providing research funding through the Fundamental Regular Research scientific grant program in 2024 No. 027/E5/PG.02.00.PL/2024.

REFERENCES

Adeyeye AS, Togun AO, Akanbi WB, Adepoju IO, Ibirinde DO (2014). Pod shattering of different soybean varieties, *Glycine max* (L.) Merrill, as affected by some growth and yield parameters. *Int*. *J. Agric*. *Pol*. *Res*. 2(1): 10–15.

Afroz M, Thirumala RV, Sridhar V, Hari Y (2022). Assessment of genetic variability in mung bean [*Vigna radiata* (L.) Wilczek.]. *J. Pharm. Innov*. 11(11): 1371–1373.

Amitrano C, Arena C, De Pascale S, De Micco V (2020). Light and low relative humidity increase antioxidants content in mung bean (*Vigna radiata* L.) sprouts. *Plants*, 9(9), 1093. doi: 10.3390/plants9091093.

Balitkabi (Balai Penelitian Tanaman Aneka Kacang dan Umbi) (2018). Hasil Utama Penelitian Tanaman Aneka Kacang dan Umbi Tahun 2018. Balitkabi, Indonesia.

BMKG (Badan Meteorologi, Klimatologi, dan Geofisika) (2024). Average temperature, humidity, rainfall, and sunshine duration in Bogor Regency, West Java, Indonesia. BMKG, Indonesia.

BPS (Badan Pusat Statistik) (2023). Harvested area, production, and productivity of mung bean 2021–2022. https://sumbar.bps.go.id/id/statistics-table/2/NjEjMg==/luas-panen-produktivitas-dan-produksi-kacang-hijau-.html (accessed March 10, 2025).

Degefa I, Petros Y, Andargie M (2014). Genetic variability, heritability and genetic advance in mungbean (*Vigna radiata* L. Wilczek) accessions. *Plant Sci. Today*, 1(2): 94–98. doi: 10.14719/pst.2014.1.2.54.

Dirjen Tanaman Pangan (2023). Laporan Tahun 2023. Kementrian Pertanian Republik Indonesia, Indonesia.

DPKP (Dinas Pertanian dan Ketahanan Pangan) (2023). Gebyar perbenihan tanaman pangan tahun 2023. DPKP Daerah Istimewa Yogyakarta, Indonesia.

Dutt A, Singh PK, Dutt A, Singh M, Singh A (2020). Study of genetic variability, heritability, and genetic advance for seed yield in mungbean (*Vigna radiata* [L.] wilczek). *J. Pharmacogn. Phytochem.* 9(6): 2245–2246.

Gogoi LR, Behera PP, Borah N, Sarma RN (2021). Genetic variability and correlation analysis for yield and yield-attributing traits in mung bean [*Vigna radiata* (L). Wilczek]. *Int. J. Chem. Stud.* 47(11): 1851–1857. doi: 10.22271/chemi.2021.v9.i1ak.11626.

Hamidah, Sunaryo W, Rusdiansyah, Nurhasanah (2024). Genetic diversity and cluster analysis of local pigmented rice from East and North Kalimantan, Indonesia based on quantitative and qualitative characters. *Biodiversitas*, 25(5): 1938–1945. doi: 10.13057/biodiv/d250510.

Hussain F, Khan EA, Baloch MS, Ullah A, Khakwani AA, Ullah Q (2022). Impact of seasonal variability on phenological development and productivity of mung bean (*Vigna radiata* [L.] Wilzeck) in arid climatic condition. *Appl. Ecol. Environ. Res.* 20(4):2985–2999. doi: 10.15666/aeer/2004_29852999.

IITA (International Institute of Tropical Agriculture) (1986). A laboratory method for evaluating resistance to pod shattering in soybeans. IITA, Ibadan.

Krisnawati A, Adie MM (2017). Variability on morphological characters associated with pod shattering resistance in soybean. *Biodiversitas,* 18(1): 73–77. doi: 10.13057/biodiv/d180111.

Krisnawati A, Soegianto A, Waluyo B, Adie MM (2022). Influence of the different pod positions and screening methods on soybean pod shattering. *Kuwait J. Sci*. 49:1–18. doi: 10.48129/kjs.v49i1.10835.

Lestari SAD, Wijanarko A, Kuntyastuti H (2019). Tanggap pertumbuhan dan hasil tiga varietas kacang hijau terhadap lama genangan. *J. Agron. Indonesia,* 47(1):32–38. doi: 10.24831/jaiv47i1.18047.

Marwiyah S, Suwarno WB, Wirnas D, Trikoesoemaningtyas, Sutjahjo SH (2021). Genotype by environment interaction on phenology and synchronous maturity mung bean. *Agronomy J*. 113:2321–2334. doi: 10.1002/agj2.20691.

Maulida H, Sutjahjo SH, Wirnas D, Marwiyah S (2022). Keragaan dan respon seleksi pada segregan transgresif kacang hijau. *J. Agron. Indonesia,* 50(2): 147–154. doi: 10.24831/jai.v50i2.40674.

Ministry of Agriculture (2022). Statistic of Food Consumption 2022. Center for Agricultural Data and Information System, Indonesia.

Mogali S, Biradar NK, Ranjita H, Balol G, Jaggal L (2023). Development of mungbean genotypes for shattering tolerance and correlation analysis with biochemical and morphological factors governing pre harvest sprouting. *Legume Res.* 5089: 1–8. doi: 10.18805/lr-5089.

Mohammed YA, Abdulkafoor AH (2018). Effect of five nitrogen levels in growth and yield of four mung bean genotypes (*Vigna radiata* L.). *Plant Arch.* 18(2): 2705–2711.

Mukhlisin, Sutjahjo SH, Ritonga AW (2025). Genetic variability, characters association, and path analysis in sweet-waxy corn. *Sabrao J. Breed. Genet.* 57(1): 25–36. doi: 10.54910/sabrao2025.57.1.3.

Parker TA, Lo S, Gepts P (2021). Pod shattering in grain legumes: Emerging genetic and environment-related patterns. *Plant Cell* 33: 179–199. doi: 10.1093/plcell/koaa025.

Pataczek L, Zahir ZA, Ahmad M, Rani S, Nair R, Schafleitner R, Cadisch G, Hilger T (2018). Bean with benefits-the role of mungbean (*Vigna radiata*) in a changing environment. *Am. J. Plant Sci*. 09:1577–1600. doi: 10.4236/ajps.2018.97115.

Priyanto SB, Azrai M, Syakir M (2018). Genetic variance, heritability, and path analysis on agronomic characters of single crosses hybrid maize. *Informatika Pertanian,* 27 (1): 1–8.

Putri ID, Sutjahjo SH, Jambormias E (2014). Evaluasi karakter agronomi dan analisis kekerabatan 10 genotipe lokal kacang hijau (*Vigna radiata* L. Wilczek). *Bul. Agrohorti,* 2(1): 11–21. https://d10.29244/agrob.2.1.11-21.

Qonita A, Rini EP, Marwiyah S, Sutjahjo SH (2022). Evaluation of plant performance and synchronous maturity of F_4 mung beans. *J. Agron. Indonesia* 50 (3): 283–290. doi:10.24831/jai.v50i3.40597.

Rehman AU, Khan ME, Kaukab S, Saeed S, Aqeel M, Riasat G, Rafiq CM (2019). Prospects of mungbean as an additional crop in rice wheat system of Punjab Pakistan. *Univers. J. Agric. Res*. 7(3):136–141. doi: 10.13189/ujar.2019.070303.

Rospita L (2023). Uji daya hasil 22 galur kacang hijau (*Vigna radiata* L.) hasil pemuliaan IPB (Skripsi). IPB University, Bogor, Indonesia.

Sefiana AN (2024). Evaluasi potensi hasil dan ketahanan pecah polong galur kacang hijau (*Vigna radiata* L.) (Skripsi) IPB University, Bogor, Indonesia.

Shintawati N, Anwar S, Kusmiyati F (2022). Evaluation of diversity and selection progress of long beans (*Vigna unguiculata* [L.]) generation F6 based on agronomic characters. *J. Agric*. *Sci*. 19: 165–174.

Suparno A, Arbianto MA, Prabawardani S, Chadikun P, Tata H, Luhulima FDN (2024). The identification of yield components, genetic variability, and heritability to determine the superior cocoa trees in West Papua, Indonesia. *Biodiversitas,*25(6): 2363–2373. doi: 10.13057/biodiv/d250605.

Sutjahjo SH, Kholisoh N, Marwiyah S, Jambormias E, Wirnas S (2022). Agronomical traits performance and variability of SSD F4 mungbean population. *Jurnal Natural* 23(2): 115–121. doi: 0.24815/jn.v23i2.24136.

Tania D, Marwiyah S, Sutjahjo SH (2023). Keragaman karakter agronomi populasi m2 kacang hijau (*Vigna radiata* L. Wilczek). *Bul. Agrohorti* 11(2): 175–184. doi: 10.29244/agrob.v11i2.47125.

Vairam N, Lavanya SA, Vanniarajan C (2017). Screening for pod shattering in mutant population of mungbean (*Vigna radiata* [L.] Wilczek). *J. Appl. Nat. Sci*. 9: 1787–1791.

Wani MR, Kozgar MI (2016). Induction of early flowering and maturing mutants in mung bean. *Int. J. Agric. Sci*. 7(1): 79–88.

Waniale A, Wanyera N, Talwana H (2014). Morphological and agronomic traits variations for mungbean variety selection and improvement in Uganda. *Afr. Crop Sci. J.* 22: 123–136.

Willem A (2023). Evaluasi ketahanan pecah polong dan tingkat produktivitas 22 genotipe kacang hijau (*Vigna radiata* L.) hasil seleksi IPB (Skripsi). IPB University, Bogor, Indonesia.

Wirnas D, Oktanti N, Rahmi HN, Andriani D, Faturrahman, Rini EP, Marwiyah S, Trikoesoemaningtyas, Sopandie D (2022). Genetic analysis for designing an ideotype of high-yielding sorghum based on existing lines performance. *Biodiversitas*, 22(12): 5286–5292. doi: 10.13057/biodiv/d221208.

Yi-Shen Z, Shuai S, FitzGerald R (2018). Mung bean proteins and peptides: Nutritional, functional and bioactive properties. *Food and Nutrition Research* 62: 1290.

Zhang Q, Tu B, Liu C, Liu X (2018). Pod anatomy, morphology and dehiscing forces in pod dehiscence of soybean (*Glycine max* [L.] Merrill). *Flora* 248: 48–53.