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# MULTIVARIATE ANALYSIS IN EXOTIC MUNG BEAN (*VIGNA RADIATA* L.) GENOTYPES FOR YIELD ATTRIBUTES

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## SUMMARY

The following research comprised the evaluation of one local cultivar, 'Durdona,' and 15 exotic genotypes of mung bean (*Vigna radiata* L.) for mean performance and traits association through morpho-yield attributes under field conditions of Tashkent Region, Uzbekistan. Results showed exotic mung bean lines AVMU2003, AVMU2004, AVMU1681, and AVMU2002 have better performance for morpho-yield traits than other genotypes. The correlation analysis revealed a significant positive relationship between the grains per pod and grain weight per pod, as well as grain weight per pod and 1000-grain weight. The traits of number of grains per pod and grain weight per pod had a positive effect and major contribution in managing the seed yield in mung beans.

**Keywords:** Mung bean (*V. radiata* L.), multivariate analysis, morpho-yield traits, correlation, plant height, pods, seed yield, Tashkent Region

**Key findings:** Genotypes AVMU2003, AVMU2004, AVMU1681, and AVMU2002 have shown better performance for morpho-yield traits than other genotypes. These genotypes' use can be effective in future breeding programs for improvement in mung beans.

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## INTRODUCTION

The mung bean (*Vigna radiata* L. Wilczek) is a highly valuable and short-lived legume of the family Fabaceae. It is rich in protein, widely adaptable to various environmental conditions, and contributes to soil fertility through biological nitrogen fixation (Sagar *et al.,* 2017). The mung bean is essentially nutritious and early-maturing, with primary cultivation in South Asia, Southeast Asia, and Australia (Nair and Schreinemachers, 2020). Recently, mung beans have gained a remarkable demand in Western countries as a plant-based protein source (Aschemann-Witzel *et al.,* 2020).

Mung bean is easy to digest and contains 22%–28% seed protein, 1%–1.5% fat, and 60%–65% carbohydrates, along with various vitamins, minerals, and antioxidants (Sandhu and Singh, 2021). With its nutritional values, the mung bean is an ingredient in various culinary applications based on local preferences. Its common consumption is as dal soup; however, it also becomes processed into noodles, porridge, curries, ice cream, cakes, bean paste, soups, sweets, and flour (Dahiya *et al*., 2015). Moreover, cooking the seeds is typical as dry beans, sprouted grams, and split dal in India and Bangladesh (Aski *et al.,* 2021) and as vegetable bean sprouts in other regions (Nair and Schreinemachers, 2020). Additionally, mung bean seeds, fodder, and haulms crucially serve as fertilizer and animal feed (Kim *et al.,* 2015).

The mung bean is highly adaptable to harsh environmental conditions, requiring minimal water and fertilizer inputs, and thrives across a wide range of temperate and tropical climates (Tantasawat *et al.,* 2015). Despite its versatility, breeding efforts in Asia have been limited, leading to a significant knowledge gap in key agronomic traits, such as seed size, shape, and color. These traits are crucial for varietal improvement, making them an important focus for future research through various breeding programs (Roychowdhury *et al.,* 2012).

Cultivating leguminous crops, including mung beans, after harvesting winter wheat, potatoes, mustard, and sugarcane enhances the soil fertility by introducing organic matter, micro- and macro-elements, and high biomass value, particularly in ecologically degraded regions. However, hindrances to the widespread adoption of summer mung bean result from high labor costs for hand-picking, low stem height, bushy growth, susceptibility to climatic vagaries, and vulnerability to diseases and pests, reducing the yield. Mechanized harvesting is more feasible with strong stems, upright growth, and appropriate branching in mung beans. Recently conducted research led to the development of mung bean cultivars ideal for mechanized harvesting, which include strong and tall stems, upright plants, and large and transparent grains, with high yield potential (Annicchiarico *et al.,* 2019).

In photoperiod- and temperature-sensitive crops, including mung beans, higher yield, stress resistance, and broader adaptability are critical characteristics. The mung bean is a short-day plant traditionally grown in Asian countries with global consumption. Despite its long-standing history, limited research has progressed on its genetic improvement. The mung bean cultivar Zhonglv-5, developed through crossbreeding in China in the early 2000s, has played a vital role in improving its cultivation in China. This cultivar offers resistance to various stresses, wide adaptability, and the highest seed yield (Adebisi *et al.,* 2004). Zhonglv-5 is an early-maturing cultivar that grows upright, with stems resistant to lodging. Therefore, the said cultivar is fully suitable for mechanized harvesting, which contains 23.1%–25.1% protein and 50.5%–51.9% starch.

Providing adequate food for the growing population has become an economic, social, and political challenge. Meeting the demand for vegetable protein is one of the key solutions to addressing this issue. The mung bean is an excellent source of protein, containing 24%–28% protein, 2%–4% oil, and 46%–50% starch, along with B vitamins, lysine, and arginine. The mung bean flour can blend well with 5%–10% wheat flour to enhance its nutritional value (Hasanuzzaman *et al*., 2016; Muthuswamy *et al*., 2019; Faysal *et al*., 2022). Significant variation in sprouting resistance before harvest has been visible among mung bean genotypes, ranging from 2.09% to 100%, with resistant genotypes successfully identified (Tantasawat *et al*., 2015).

Production of mung beans faces major constraints, including late-season heat stress and pre-harvest germination during the rainy season, considerably reducing their seed yield. By shortening the maturation period (10–15 days) without yield loss, it could help mitigate these challenges. The Legume Research Institute in Kanpur, India, developed two early-maturing mung bean genotypes, maturing in 45–48 days and 10–12 days earlier than standard genotypes. These genotypes also proved resistant to yellow mosaic virus and have desirable morphological traits (Sandhu and Singh, 2021).

The mung bean is a vital early-maturing legume in India, which has historically been the world's largest producer and consumer of mung bean products. Systematic breeding efforts have led to the development of improved cultivars; however, their full genetic potential remains unrealized due to various abiotic stresses, such as high temperatures, drought, and salinity, which cause significant yield losses. Efforts to breed stress-resistant cultivars have faced challenges due to the complex nature of these stresses and the difficulties in their assessment (Muthuswamy *et al*., 2019; Khamraev *et al*., 2025).

One of the key requirements for large-scale mung bean cultivation is a high-protein-rich cultivar that could be a potential substitute for meat (Sandhu and Singh, 2021). Among legumes, the mung bean is unique for its nutritional values, with protein digestibility averaging 86%. Protein content varies depending on the plant cultivar, growth conditions, and field practices. Interestingly, when grown as a secondary crop, mung bean grain tends to have higher protein content (Hasanuzzaman *et al*., 2016). The following research aimed to develop high-yielding mung bean cultivars, well-adapted to diverse soil and environmental conditions, while studying their biological properties.

## MATERIALS AND METHODS

### Experimental site

Field experiments proceeded during the crop season of 2022–2023 at the Durmon Regional Experimental Base, Institute of Genetics and Plant Experimental Biology, District Kibray, Tashkent Region, Uzbekistan (41°20′N latitude, 69°18′E longitude). The experimental field soil is a low-humus typical sierozem with a medium sandy texture. The terrain is slightly sloping and non-saline, with minimal impact from *Verticillium* wilt. Groundwater has a depth of 7–8 meters. The climate is highly variable, with hot summers (June, July, and August) and sharply cold winters (especially in December and January). The site experiences 175–185 sunny days annually, with a frost-free period lasting 200–210 days. Rainfall occurs mainly in autumn, winter, and spring, while summers are dry, necessitating artificial irrigation for mung bean cultivation.

### Agricultural practices

Agricultural practices continued following the protocols established by the Institute of Genetics and Plant Experimental Biology. After the wheat harvest, the field’s clearing in spring occurred, with the plots plowed to a depth of 35 cm. Fertilizer applications transpired under moderate soil and air temperatures, while performing soil pulverization retained moisture and controlled weeds. Irrigation and other agronomic activities progressed throughout the growing season. Mineral fertilizers’ application both commenced before planting and through top dressing at three key growth stages: the beginning of pod formation, flowering, and pod development. The annual fertilizer application rate was 60:90:30 NPK kg/ha.

### Sowing scheme

Sowing commenced in the third week of April following a 60 cm × 10 cm × 1 cm planting scheme. The planting of seeds had a depth of

4–5 cm with three replications, with two rows in each replication and 25 seedbeds per row. Each replication included 100 plants. Inter-row cultivation and weeding ensued in combination with irrigation.

**Plant material**

The study utilized mung beans (*V. radiata* L.), including the local cultivar 'Durdona' and 15 exotic genotypes: AVMU1676, AVMU1677, AVMU1678, AVMU1679, AVMU1680, AVMU1681, AVMU1682, AVMU1683, AVMU1684, AVMU1685, AVMU2001, AVMU2002, AVMU2003, AVMU2004, and AVMU2005.

**Data recorded**

The data recorded were on various morpho-yield traits, i.e., plant height (cm), harvested branches, pods per plant, pod weight (g), grains per pod, grain weight per pod (g), and 1000-grain weight (g). The measuring of all traits used standard methods.

**Statistical analysis**

The analysis of variance (ANOVA) of mung bean genotypes proceeded according to standard protocols (Steel *et al.,* 1997). The genotype means with significant differences for each trait reached further detection using Fisher's criterion (F), standard error of the mean difference (SE), and least significant difference (LSD) levels ($P \leq 0.05$*, $P \leq 0.01$**, and $P \leq 0.001$***). Correlation coefficients' calculations among the various traits also ensued (Kwon and Torrie, 1964).

## RESULTS

By studying the morpho-yield attributes of 16 mung bean genotypes in the experiment, the highest values of plant height resulted in the genotype AVMU2002 (103.0 ± 1.01 cm), while the lowest were in the genotype AVMU1680 (57.60 ± 0.38 cm). On average, it was also noticeable that, in most mung bean genotypes, the plant height ranged from 80 to 100 cm. According to the number of harvested branches, the highest number of branches were prominent in the local cultivar 'Durdona' (9 ± 0.24) and exotic genotypes AVMU1682 and AVMU1685 (10.0 ± 0.37 and 9.40 ± 0.27, respectively). However, the fewest branches appeared in exotic genotypes AVMU1679, AVMU2002, and AVMU2003 (6.4 ± 0.25, 6.20 ± 0.25, and 6.20 ± 0.13, respectively). In the 16 mung bean genotypes, it was also evident that the number of harvested branches ranged from seven to nine.

The most pods per plant (52.80 ± 2.17) came from the exotic genotype AVMU1685, while the lowest pods were in the genotypes AVMU1677, AVMU1683, and AVMU2005 (33.80 ± 2.65, 30.0 ± 0.97, and 33.00 ± 0.73, respectively). It has also surfaced that in the exotic mung bean genotypes, the number of pods per plant mainly ranged from 30 to 50. Among the 16 mung bean genotypes, the heaviest pod weight was notable with the exotic genotypes AVMU2003 and AVMU2004 (1.24 ± 0.03 and 1.24 ± 0.03 g, respectively). The genotype AVMU1683 revealed the lightest pod weight (0.69 ± 0.01 g). Under field conditions, it was also remarkable that, in the mung bean genotypes, the pod weight mainly ranged from 0.75 to 1.00 g (Table 1).

Among mung bean genotypes, the maximum number of grains per pod occurred in genotype AVMU1681 (11.00 ± 0.31). However, the minimum number of grains per pod manifested in the exotic genotypes AVMU2004 and AVMU2005, with 9.40 ± 0.41 and 9.30 ± 0.31 grains per pod, respectively. The ultimate total grain weight per pod resulted in the exotic genotype AVMU2003 (0.88 ± 0.03 g), while the lowest values for this trait were notable in genotypes AVMU1679, AVMU1680, and AVMU1682 (0.49 ± 0.02, 0.49 ± 0.01, and 0.46 ± 0.01 g, respectively). From the 16 mung bean genotypes, the grain weight per pod ranged from 0.50 to 0.80 g.

The results further revealed that under field conditions in the Tashkent Region, the determined 1000-grain weight mainly varied from 50 to 70 g in the mung bean genotypes. The maximum 1000-grain weight appeared in

**Table 1**. Morpho-yield traits of one local cultivar and 15 exotic mung bean genotypes under field conditions of Tashkent Region, Uzbekistan.

| No. | Genotypes | Plant height (cm) | Harvested branches (#) | Pods per plant (#) | Pod weight (g) | Grains per pod (#) | Grain weight pod$^{-1}$ (g) | 1000-grain weight (g) |
|---|---|---|---|---|---|---|---|---|
| | | ME±SE | ME±SE | ME±SE | ME±SE | ME±SE | ME±SE | ME±SE |
| 1 | Durdona | 63.0 ±1.01 | 9±0.24 | 41.0±2.20 | 0.94±0.02 | 10.6±0.24 | 0.63±0.02 | 54.8±0.08 |
| 2 | AVMU1676 | 73.4 ±0.64 | 7.0 ±0.18 | 38.8±2.88 | 0.87±0.03 | 10.6±0.23 | 0.58±0.02 | 53.0±0.17 |
| 3 | AVMU1677 | 89.4±1.03 | 7.0 ±0.30 | 33.8±2.65 | 0.88±0.02 | 10.7±0.24 | 0.61±0.01 | 53.4±0.08 |
| 4 | AVMU1678 | 83.4±0.64 | 7.0 ±0.18 | 40.6±2.42 | 0.82±0.02 | 9.8±0.26 | 0.57±0.01 | 53.4±0.14 |
| 5 | AVMU1679 | 89.0 ±1.12 | 6.4 ±0.25 | 41.0±3.23 | 0.75±0.03 | 10.0±0.36 | 0.49±0.02 | 44.5±0.12 |
| 6 | AVMU1680 | 57.6 ±0.38 | 7.2 ±0.25 | 43.4±3.03 | 0.71±0.02 | 9.8±0.17 | 0.49±0.01 | 50.3±0.09 |
| 7 | AVMU1681 | 91.4 ±2.54 | 6.8 ±0.13 | 38.8±2.55 | 0.99±0.02 | 11.0±0.31 | 0.71±0.02 | 62.1±0.15 |
| 8 | AVMU1682 | 77.4±0.74 | 10.0 ±0.37 | 48.4±2.33 | 0.69±0.01 | 9.5±0.23 | 0.46±0.01 | 44.9±0.15 |
| 9 | AVMU1683 | 77.4 ±3.03 | 8.2 ±0.22 | 30.0±0.97 | 0.80±0.03 | 10.8±0.34 | 0.54±0.02 | 49.8±0.20 |
| 10 | AVMU1684 | 89.8 ±0.43 | 7.0±0.11 | 40.8±1.88 | 0.77±0.03 | 9.7±0.33 | 0.52±0.02 | 52.2±0.14 |
| 11 | AVMU1685 | 85.4 ±1.30 | 9.4 ±0.27 | 52.8±2.17 | 0.79±0.03 | 9.4±0.38 | 0.53±0.02 | 53.4±0.26 |
| 12 | AVMU2001 | 82.8±0.66 | 8.2 ±0.13 | 41.0±0.99 | 0.85±0.01 | 10.8±0.22 | 0.59±0.01 | 51.8±0.23 |
| 13 | AVMU2002 | 103.0 ±1.01 | 6.2 ±0.25 | 46.4±3.16 | 0.95±0.02 | 10.5±0.26 | 0.67±0.01 | 67.3±0.30 |
| 14 | AVMU2003 | 87.0±0.86 | 6.2 ±0.13 | 37.4±1.76 | 1.24±0.03 | 10.6±0.31 | 0.88±0.03 | 74.8±0.28 |
| 15 | AVMU2004 | 94.0±0.98 | 8.2 ±0.27 | 42.6±2.13 | 1.02±0.04 | 9.4±0.41 | 0.64±0.03 | 67.2±0.25 |
| 16 | AVMU2005 | 80.0 ±1.60 | 7.6±0.13 | 33.0±0.73 | 0.87±0.01 | 9.3±0.31 | 0.54±0.01 | 59.4±0.14 |

**Table 2.** Correlation coefficient among the morpho-yield traits in exotic mung bean genotypes.

| Traits | Plant height (cm) | Harvested branches (#) | Pods per plant (#) | Pod weight (g) | Grains per pod (#) | Grain weight pod$^{-1}$ (g) | 1000-grain weight (g) |
|---|---|---|---|---|---|---|---|
| Plant height (cm) | | -0.3777 | 0.0782 | 0.4709 | 0.0326 | 0.3461 | 0.4500 |
| Harvested branches (#) | | | 0.3834 | -0.4491 | -0.3466 | -0.4834 | -0.3933 |
| Pods per plant (#) | | | | -0.2467 | -0.4371 | -0.1157 | -0.0868 |
| Pod weight (g) | | | | | 0.4262 | 0.8943*** | 0.9055*** |
| Grains per pod (#) | | | | | | 0.5252* | 0.1575 |
| Grain weight per pod (g) | | | | | | | 0.8143*** |

the exotic genotype AVMU2003 (74.8 ± 0.28 g), while the minimum values for the said trait manifested in the exotic mung bean genotypes AVMU1679, AVMU1683, and AVMU1684 (44.5 ± 0.12, 44.9 ± 0.15, and 49.8 ± 0.20 g, respectively).

In the said experiment, Pearson correlation, as performed on morpho-yield traits of 15 exotic genotypes and one local cultivar of mung bean, displayed a significant positive correlation (*r* = 0.89*** and *r* = 90***, respectively) in pod weight with the pod grain weight and 1000-grain weight. A moderate positive correlation (*r* = 0.50*) was evident between the trait's grains per pod and grain weight per pod. A strong positive correlation (*r* = 81***) emerged between the grain weight per pod and 1000-grain weight. Correlation analysis showed the number of grains per pod and grain weight per pod had a positive effect and major contribution in managing the seed yield in mung beans (Table 2).

The agglomeration schedule indicated which observations were combining at each stage of the clustering process (Table 3). In the first stage, observation 4 was conservation 10. The distance between the groups when combined was 0.55023. It also revealed that at stage 3, this combined group further joined with another cluster (Figure 1).

## DISCUSSION

The information on genetic variability and the association between the agronomic traits and seed yield play an influential role in supporting mung bean breeding programs. The genetic variation among the mung bean genotypes

**Table 3.** Cluster analysis of exotic mung bean genotypes.

| Stages | Combined Cluster 1 | Combined Cluster 2 | Distance | Previous stage Cluster 1 | Previous stage Cluster 2 | Next Stage |
|---|---|---|---|---|---|---|
| 1 | 4 | 10 | 0.55023 | 0 | 0 | 3 |
| 2 | 2 | 12 | 1.2684 | 0 | 0 | 5 |
| 3 | 4 | 5 | 2.01674 | 1 | 0 | 11 |
| 4 | 8 | 11 | 2.88896 | 0 | 0 | 14 |
| 5 | 2 | 3 | 3.79068 | 2 | 0 | 7 |
| 6 | 7 | 13 | 4.8125 | 0 | 0 | 10 |
| 7 | 2 | 9 | 6.088 | 5 | 0 | 9 |
| 8 | 15 | 16 | 7.40865 | 0 | 0 | 12 |
| 9 | 1 | 2 | 8.81238 | 0 | 7 | 13 |
| 10 | 7 | 14 | 10.5888 | 6 | 0 | 15 |
| 11 | 4 | 6 | 12.4425 | 3 | 0 | 12 |
| 12 | 4 | 15 | 14.6562 | 11 | 8 | 13 |
| 13 | 1 | 4 | 17.5171 | 9 | 12 | 14 |
| 14 | 1 | 8 | 21.1429 | 13 | 4 | 15 |
| 15 | 1 | 7 | 26.4662 | 14 | 10 | 0 |

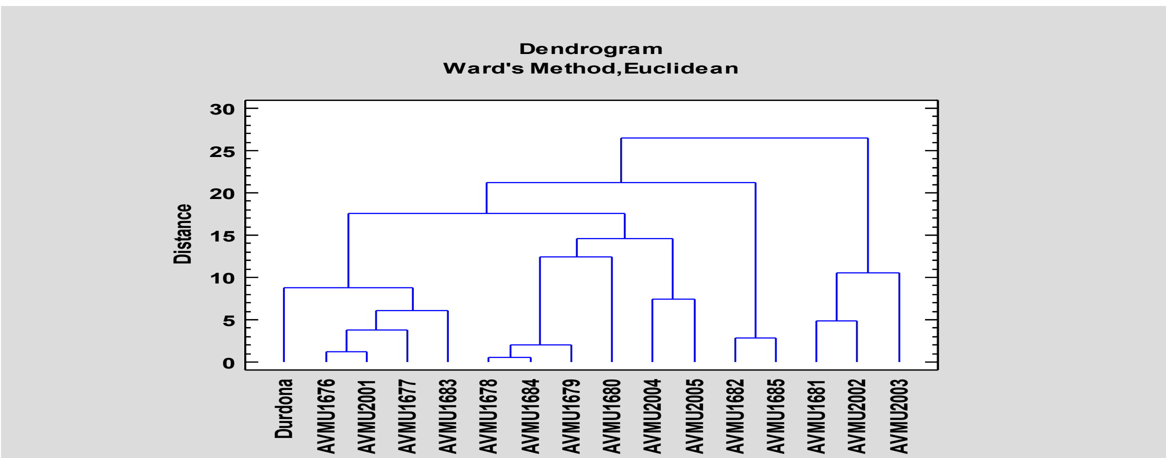


**Figure 1.** Dendrogram analysis of exotic mung bean genotypes.

proved to be significant for most traits studied, especially maturity, plant height, pods per plant, and seed size. Among the seed yield components, the number of pods per plant and plant height appeared to be positively correlated with yield; however, they emerged negatively correlated with grain size. The outcomes showed that the number of pods per plant and plant height had the greatest direct impact on grain yield (Sen and De, 2017; Annicchiarico *et al.,* 2019).

Accurate genotypic descriptions and organization of genetic diversity would help to determine breeding strategies and facilitate appropriate choices for germplasm conservation (Tian *et al.,* 2023; Alpamyssova *et al.,* 2024). In the presented study, the 16 mung bean genotypes have shown characteristics using seven morphological features as per the standard list of descriptors for mung beans. Morphological characterization has been crucial in determining the genetic diversity in the mung bean. For an effective and accurate evaluation, maintenance, the genotype's performance, and the level of genetic diversity require investigation (Sarkar and Kundagrami, 2016; Carrillo-Perdomo *et al.,* 2020).

Globally, the primary objective of mung bean breeding programs is to breed for high production potential, preferred grain quality, and resistance to abiotic and biotic stress conditions. These goals can be successful because of the considerable genetic variation within the existing germplasm available to the breeders. Breeders must regularly exchange germplasm locally and globally to achieve the breeding aims. Investigating the level of genetic diversity is crucial for the proper evaluation, management, and exploration of the available germplasm (Glenn *et al.,* 2017; Idrisov, 2022).

The breeding program mainly depends upon the degree of genetic diversity, with the morphological characterization regarded as an essential step in the description and categorization of plant genetic resources (Yeginbay *et al.,* 2024). Screening for qualitative traits is essential for characterizing crop plants and has become crucial for the registration and certification of various crops (Azimov *et al*., 2023; Yeginbay *et al*., 2023; Narimonov *et al*., 2023; Rajabov *et al*., 2024).

## CONCLUSIONS

The morpho-yield characteristics revealed that the local cultivar 'Durdona' and exotic genotypes of mung bean AVMU2003, AVMU2004, AVMU1681, and AVMU2002 showed better performance than other genotypes. Moreover, a significant positive correlation existed between the grains per pod and grain weight per pod, as well as between total grain weight per pod and 1000-grain weight.

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