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Assessment of Genetic Variability, Performance and Evaluation of Mungbean [*Vigna radiata* (L.)Wilzeck] Genotypes for Agro-Morphological and Physio-Biochemical Traits under Arid Zone Conditions of Rajasthan

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ABSTRACT

Mungbean, a climate-resilient legume, encounters productivity obstacles owing to escalating abiotic stresses. This investigation evaluated 35 genotypes in the arid Rajasthan's region to evaluate the genetic variability of 17 yield and stress-adaptive characters. The study aimed to identify high-performing genotypes exhibiting superior drought tolerance and yield potential, providing pivotal data to facilitate the development of climate-smart varieties and bolster food security in water-constrained environments. A total of thirty-five mungbean genotypes were assessed through a randomized block experimental design, with three replications conducted across four distinct environments at SKRAU, Bikaner, Rajasthan, during the summer of 2019 and the Kharif season of 2019-20. Standard agronomic practices were implemented throughout the evaluation process. Furthermore, genetic parameters were estimated via variance component analysis utilizing R-software, following established quantitative genetic methodologies. ANOVA revealed highly significant differences among the genotypes across all the evaluated traits. Particularly noteworthy was the substantial variation observed in stress-responsive parameters, including membrane stability index, proline content, and relative water content. The genotypes exhibited high levels of both genotypic and phenotypic coefficients of variation for proline content, biological yield, and harvest index. Furthermore, traits such as days to maturity, plant height, number of pods per plant, membrane stability index, proline content, biological yield, harvest index, and seed yield exhibited high heritability estimates coupled with a high genetic advance as a percentage of the mean, suggesting that additive gene action governs these characters and selection would be effective. The superior performing genotypes encompassed GM-4, RMG-344, and RMG-62. Notably, genotypes such as IC-52081, IC-52087, and GM-4 recorded high proline content and membrane stability index, which are indicative of enhanced drought tolerance. Additionally, SML-832 exhibited the highest relative water content, indicating better water retention under limited moisture conditions.

Keywords: *Mungbean, membrane stability index (MSI), proline content, relative water content (RWC), stress tolerance, variability parameter and yield components.*

INTRODUCTION

In India, mungbean, commonly known as green gram, and other pulses are essential supplements to cereal-based diets. This ancient crop is cultivated across diverse agro-ecological environments, particularly during the Kharif and summer seasons (Kumar *et al.*,2024).*Vigna radiata* is taxonomically classified as a diploid species within the Leguminosae family, specifically the Papilionaceae subfamily (Anita *et al.*,2022). *Vigna radiata* var. sublobata, native to South Asia, is considered the likely progenitor of mungbean. The crop predominantly exhibits self-pollination (Singh *et al.*, 2015).

In India, the cultivation of mungbean is predominantly observed during the Kharif season. The country's contribution to the global landscape of mungbean production is noteworthy, accounting for 65% of the world's acreage and 54% of total production volume. Within the state of Rajasthan, mungbean farming extends across an area of 2.364 million hectares, yielding a production output of 0.812 million tonnes, with a productivity rate of 344 kilograms per hectare(Anonymous, 2023-24).

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Despite India's leading role in global green gram production, its realized productivity remains suboptimal relative to its potential. Consequently, there exists a substantial opportunity for enhancement through the breeding and development of superior cultivars characterized by elevated yield potential, resistance to prevalent biotic stressors, and improved nutritional attributes. Given the predominantly autogamous nature of mungbean reproduction, the inherent genetic variability for agronomically important yield traits is constrained, thereby limiting the efficacy of conventional selection methodologies. However, a comprehensive characterization of the extant genetic diversity for key yield components, in conjunction with estimations of heritability parameters and predicted genetic advance, may prove invaluable for plant breeders endeavoring to identify elite genotypes for crop improvement initiatives (Degafa*et al.*,2014).
Mungbean is a chief source of protein in arid and semi-arid climates, representing about 25% of India's pulse production (Yadav*et al.*, 2019). Its short growth cycle and ability to withstand drought make it especially useful for rainfed agriculture (Nair *et al.*, 2021).

Nevertheless, yields are generally low due to a lack of genetic improvement and vulnerability to abiotic stresses (Singh *et al.,* 2020).

Mungbean, a crucial short-season legume, is extensively grown in arid and semi-arid areas because of its resilience to drought and significant nutritional content (Singh *et al.,* 2020). Nevertheless, abiotic stresses, notably limited water availability and high temperatures intensified by climate change in areas such as Rajasthan, continue to hinder its yield (Kumar *et al.,* 2021). Genetic variability constitutes a fundamental resource for enhancing crop performance, facilitating the breeding of stress-resistant varieties suited to challenging environmental conditions (Patel *et al.,* 2022).

Mungbean exhibit substantial genetic diversity in agro-morphological and physiological traits, including flowering time, plant height, pod number, and stress-adaptive mechanisms like proline accumulation and membrane stability (Dhole & Reddy, 2015). The high heritability and genetic advance observed in yield-related characters suggest a principal role of additive gene action, offering strong potential for selection-based breeding strategies (Tiwari*et al.,* 2019). However, comprehensive evaluations of mungbean genotypes under arid conditions remain limited, particularly regarding the integration of physiological resilience with yield enhancement.

This study was designed to comprehensively evaluate 35 diverse mungbean genotypes under the arid conditions of Rajasthan with three primary objectives: (1) to quantify genetic variability for 17 agro-morphological and physio-biochemical characters, (2) to estimate heritability and genetic advance for yield components and stress-adaptive characteristics, and (3) to identify superior genotypes combining high yield potential with climate resilience. The investigation specifically focuses on critical drought-responsive traits including membrane stability index, proline accumulation and relative water content, which serve as key indicators of adaptive capacity under water-limited conditions.

MATERIALS AND METHODS

Experimental Site

The field experiments were conducted at the Experimental Farm of the College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, situated at 28.0229°N, 73.3119°E, with an elevation of 237 m above mean sea level. According to the National Agricultural Research Project, Bikaner is situated in Agro-climatic Zone IC of Rajasthan, and according to the National Planning Commission, it is located within Agro-climatic Zone XIV of India. The experimental site has an arid climate, with an average annual rainfall of approximately 265 mm, with the majority occurring during the Kharif season as a result of the South-West monsoon. Temperatures can reach as high as 48°C in summer and fall to as low as 0°C in winter. The region is also prone to high wind speeds and soil erosion caused by summer dust storms.

Plant Materials

Thirty-five mungbean genotypes were sourced from a range of research institutions. A detailed list of all genotypes, including their accession information and sources, is presented in Table 1.

Experimental Design and Layout

Field investigations were carried out at the Swami Keshwanand Rajasthan Agricultural University, Bikaner, across 2 growing periods(summer 2019 and Kharif 2019-20). A randomized block design, replicated three times, was utilized in this study. Each experimental plot comprised two rows, each 3 meters in length, separated by a 30 cm interval. A consistent 10 cm spacing between plants was achieved by thinning the seedlings. Four distinct environmental conditions were created through differential sowing dates (i) Summer season: early sowing (06 March) and late sowing (20 March); (ii) Kharif season: early sowing (06 July) and late sowing (20 July).Consistent application of recommended agronomic practices across all treatments aimed to promote optimal crop development.

Data Collection

A total of 17 traits, encompassing both agro-morphological and physio-biochemical characteristics, were evaluated. The agro-morphological traits included: days to 50 per-cent flowering, days to maturity, plant height, number of pods per plant, number of seeds per pod, pod length, 100-seed weight, biological yield per plant, seed yield per plant, and harvest index. The physio-biochemical traits comprised: chlorophyll a, b, and total chlorophyll content, membrane stability index, relative water content, proline content, and crude protein content. Data for days to 50 per-cent flowering and days to maturity were collected on a plot basis. The remaining agro-morphological observations were recorded from five randomly selected plants within each entry. The physio-biochemical traits were assessed using the methods outlined below:

1. Chlorophyll content (mg g^{-1} fresh weight) in leaves at 50 per-cent flowering: Total chlorophyll content was assessed using the Hiscox and Israelstam method, (1979). A sample extract was created by placing 50 mg of leaf tissue in 5 ml of DMSO (Dimethyl sulphoxide). These samples underwent incubation at 65°C for 4 hours. Following a cooling period to room temperature, the absorbance of the extracts was measured at wavelengths of 470, 663, and 645 nm. Chlorophyll content was then determined using a specified calculation.

$Chl\ a = [12.7 \times A_{663} - 2.69 \times A_{645}]$

$Chl\ b = [22.9 \times A_{645} - 4.68 \times A_{663}]$

$Chl_{Total} = [20.2 \times A_{645} + 8.02 \times A_{663}]$

The resulting values are expressed in µg/ml of extract (solvent). To convert these values to mg/g fresh weight, the values were multiplied by the ratio "V/(W x1000)" where V represents the volume of the extract (in ml)and W denotes the fresh weight (in gram)of the sample.

2. Membrane stability index (%) in leaves at 50 per cent flowering: The membrane stability index (MSI) was assessed using the method described by Premchand*et al.*, (1990)with modifications by Sairam*et al*(1997). To determine the membrane stability index, 100 mg of leaf material was collected in duplicate(in two sets) and placed in test tubes containing 10 ml of double-distilled water. One set of samples was heated to 40°C for 30 minutes in a metabolic water bath, then cooled to room temperature, and the electrical conductivity of the solution was measured using a conductivity bridge (C_1). The second set of samples was boiled at 100°C in a boiling water bath for 10 minutes, then cooled to room temperature, and its conductivity was measured using a conductivity bridge (C_2). The membrane stability index was then calculated as under:

Membrane stability index (MSI) = $[1-(C_1/C_2)] \times 100$

Where,

C_1 represents the electrical conductivity of the sample solution after being heated to 40^0C

C_2 represents the electrical conductivity of the sample solution after being subjected to a temperature of 100^0C

3. Relative water content (%) in leaves at 50 per cent flowering : Leaf segments (1 cm^2) were initially weighed and then floated on distilled water for a day (24 hours) to achieve full turgidity, after which their turgid weight was recorded. Subsequently, the segments were dried in a hot air oven at 80°C for two days (48 hours) to determine their dry weight. Relative water content was then calculated using Slavik's(1974)formula as under:

Relative water content (RWC) = $\frac{\text{Fresh weight}-\text{Dry weight}}{\text{Turgid weight}-\text{Dry Weight}} \times 100$

4. Proline content

Free proline was extracted from leaves (mg g^{-1} fresh weight) and quantified following the Bates *et al.* (1973) method. A 100 mg fresh leaf sample was homogenized in five ml of three per cent aqueous sulphosalicylic acid, and the supernatant was collected via centrifugation at 5000 rpm for 5 minutes. The supernatant volume was adjusted to 10 ml with sulphosalicylic acid. A two ml aliquot of the sample extract was transferred to a test tube, alongside a series of test tubes containing 0.2, 0.4, 0.6, 0.8, and 1.0 ml proline standards, which were prepared by dissolving 10 mg of proline in 100 ml of three per cent sulphosalicylic acid. A separate tube containing two ml of sulphosalicylic acid served as the blank.

In each test tube, two ml of ninhydrin reagent(1.25 g ninhydrin in 20 ml of 6N ortho-phosphoric acid) and two ml of glacial acetic acid were combined and incubated in a boiling water bath at 100°C for 10 minutes. The reaction was subsequently halted by cooling the mixture in an ice bath. Following this, four ml of toluene was introduced, and the solution was mixed vigorously for 10 seconds using a vortex mixer. Absorbance was quantified at 520 nm using a UV-visible spectrophotometer(Systronics-2203), with a reagent blank as a reference. The concentration of free proline within the 100 mg leaf sample was then determined by referring to a standard curve.

5. Crude protein content (%)

The Microkjeldahl method was employed to estimate the nitrogen content in the samples. A measured quantity of each sample was digested in a Kjeldahl flask using concentrated sulfuric acid and a digestion mixture (Potassium sulphate and copper sulphate, 10:1). Following complete digestion, the mixture was cooled and quantitatively transferred to a 250 ml volumetric flask, with repeated washings of the Kjeldahl flask using distilled water to ensure complete transfer, and the volume was adjusted to 250 ml. After thorough mixing, a suitable aliquot was transferred to a microkjeldahl distillation apparatus. A 50% sodium hydroxide solution was added to render the contents alkaline. The distillate was collected in a conical flask containing 10 ml of 4% boric acid solution with a mixed indicator and then titrated against a standardized 0.1N H_2SO_4solution.

The determination of protein content within the samples involved multiplying the nitrogen content by a factor of 6.25.

N (g/100g sample) = $\frac{\text{Titre value x 0.0014 x Volume made x 100}}{\text{Aliquot used x Weight of sample dry matter}}$

Statistical Analysis

The method described by Panse and Sukhatme(1985) was used to compute the analysis of variance.

Utilizing the method detailed by Johnson *et al*. (1955), genotypic and phenotypic variance were estimated. Phenotypic and genotypic coefficients of variation were calculated based on Burton's (1952) proposed method. Broad-sense heritability was estimated in accordance with Lush's (1940) method. As per the suggestions of Johnson *et al*. (1955), the anticipated genetic advance for each trait was calculated.

RESULT AND DISCUSSION

1. Genetic Variability and Heritability

Significant differences among the 35 mungbean genotypes were observed for all agro-morphological and physio-biochemical traits studied, indicating the presence of ample genetic variability (Table 2). Analysis of variance revealed highly significant (P ≤ 0.01) differences among genotypes for traits such as days to 50% flowering, days to maturity, plant height, number of pods per plant, pod length, 100-seed weight, biological yield, harvest index, membrane stability index (MSI), proline content, protein content, and seed yield per plant, suggesting the existence of considerable inherent genetic variability that could be utilized in breeding programs.

The genotypic coefficient of variation (GCV) was lower than the phenotypic coefficient of variation (PCV) for all traits (Table 3), which indicates environmental influence on trait expression; however, the narrow difference between PCV and GCV for most characters suggests a minimal environmental effect. The highest GCV and PCV were recorded for proline content (30.06% and 30.11%, respectively), followed by biological yield (20.91% and 21.18%) and harvest index (19.82% and 20.15%), reflecting a higher potential for selection gains in these traits. These findings are in agreement with earlier reports by Patel *et al*., (2017) and Singh *et al*., (2019), who also noted higher variability for physiological traits under stress conditions.

Broad-sense heritability ranged from 69.80% for number of seeds per pod to 99.80% for days to maturity. Traits such as days to 50% flowering, days to maturity, 100-seed weight, biological yield, harvest index, protein content, proline content and seed yield exhibited heritability above 95%, indicating that these traits are under strong genetic control.

High heritability coupled with high genetic advance as per-cent of mean was observed for days to maturity, plant height, number of pods per plant, membrane stability index, proline content, biological yield, harvest index, and seed yield suggesting that additive gene action governs these traits and selection would be effective. These findings are consistent with those reported by Yadav*et al.*, (2020) in mungbean.

1.1 Genetic Variability and Heritability for Stress-Adaptive Traits

The ANOVA revealed highly significant ($p < 0.01$) genotypic differences for all traits (Table 2), with particularly notable variation in stress-responsive parameters: membrane stability index (MSI, 128.32), proline content (2.56), and relative water content (RWC, 59.38). These findings align with Vadez*et al.*, (2021), who identified MSI and osmotic adjustment as pivotal for drought adaptation in legumes. High heritability (>94%) for these traits (Table 3) suggests strong genetic control, supporting their use in marker-assisted selection.

2. Mean Performance of Genotypes

Among the 35 genotypes, considerable variation was recorded for seed yield per plant, ranging from 6.99 g (IC-103244) to 13.14 g (GM-4) (Table 4). Genotype GM-4 also recorded superior performance for 100-seed weight (5.15 g) and pod length (8.06 cm), which are vital yield-contributing traits.

Similarly, RMG-344 and Keshwanand Mung-1 showed a higher number of pods per plant (33.33 and 31.33, respectively), indicating their utility in yield improvement.

Notably, genotypes such as IC-52081, IC-52087, and GM-4 recorded high proline content (5.08, 4.96, and 3.30 mg/g, respectively) and MSI (above 60%), which are indicative of enhanced drought tolerance. These results support the view that physiological traits such as proline accumulation and membrane stability are crucial for screening drought-tolerant genotypes, as also reported by Thirumeni*et al.*, (2000) and Nair *et al.*, (2015).

2.1 High-Yielding Genotypes with Stress Resilience

GM-4 emerged as the top performer, combining high yield (13.14 g/plant), early maturity (64 days), and elevated RWC (76.16%). Its superior biological yield (28.13 g/plant) and harvest index (47.43%) reflect efficient resource partitioning under stress, corroborating Toker*et al.*(2022) on the linkage between early vigor and terminal drought tolerance.

RMG-344andRMG-62 exhibited dual adaptability, with high pod number (33.33 and 29.67, respectively) and stable MSI (>51%), traits critical for yield stability in variable environments (Sharma *et al.,* 2020).

3. Physiological Traits and Stress Tolerance

Genotypes exhibited substantial variability in chlorophyll content, with total chlorophyll ranging from 2.05 to 3.17 mg/g f.w. (Table 4). Genotype IC-103059 exhibited the highest total chlorophyll content (3.17 mg/g), which may relate to higher photosynthetic efficiency and yield. Relative water content (RWC) ranged from 52.09% to 76.81%, with SML-832 maintaining the highest RWC, indicating better water retention under limited moisture conditions.

Physiological traits including proline content, RWC, and MSI have shown potential in identifying genotypes resilient under abiotic stress. The strong association of these traits with seed yield suggests that they can be used as selection criteria in breeding for stress tolerance, as suggested by Hasanuzzaman*et al.*, (2013).

4. Physiological Markers for Stress Breeding

4.1 Osmoprotection: IC-52081 accumulated the highest proline (5.08 mg/g), a trait associated with cellular protection under dehydration (KaviKishor*et al.,* 2020). Its compact growth (32.38 cm height) may further confer drought escape advantages.

4.2 Photosynthetic Efficiency: IC-103059 showed the highest total chlorophyll (3.17 mg/g), while MUM-2 had the lowest (2.05 mg/g), providing a clear contrast for studying photosynthetic stability under stress.

5. Trade-offs and Breeding Implications

The negative correlation between early flowering (38 days in Sweta) and seed yield ($r = -0.62$) highlights a common breeding challenge. However, IPM-02-3 balanced these traits (70-day maturity, 9.39 g yield), suggesting opportunities for ideotype development. The high heritability (96%) and genetic advance (40.17%) for the harvest index emphasize its reliability for indirect yield selection, as proposed by Wallace *et al.*, (2023) in heat-stressed environments. Identification of superior genotypes combining high yield potential with climate resilience is given below:

Table 1: Treatments used for testing efficacy of different fungicides, botanicals, bio-agent and their combination

S. No.	Target Trait	Primary Genotype (High Expression)	Complementary Genotype (Secondary Trait)	Rationale
1	High Yield	GM-4 (13.14 g/plant)	RMG-344 (12.07 g/plant)	Both exhibit high pod number (27–33) and biological yield (>28 g/plant).
2	Drought Tolerance	IC-52081 (Proline: 5.08 mg/g)	Sweta (MSI: 63.89%)	Combines osmoprotection (proline) with membrane stability (high MSI).
3	Early Maturity	Sweta (64 days to maturity)	IPM-02-3 (70 days)	Early flowering + moderate yield (9.39 g/plant) for short-season adaptation.
4	Photosynthetic Efficiency	IC-103059 (Chl. 3.17 mg/g)	IC-39269 (Chl. 3.09 mg/g)	High chlorophyll content linked to light-use efficiency under stress.
5	Protein Enrichment	IC-52076 (25.23% protein)	IC-102857 (24.88% protein)	Dual high-protein sources for nutritional breeding.
6	Stable Pod Production	RMG-344 (33.33 pods/plant)	IC-39492 (29.67 pods/plant)	Ensures consistent yield under biotic/abiotic stress.
7	Heat Tolerance	SML-832 (RWC: 76.81%)	IC-52081 (RWC: 76.55%)	High RWC maintains turgor under high-temperature stress.

CONCLUSION

This study identifies GM-4 and RMG-344 as elite genotypes for yield-stress tolerance pyramiding. The robust heritability of MSI (94.9%) and proline content (99.6%) supports their use as selection markers. Notably, genotypes such as IC-52081, IC-52087, and GM-4 recorded high proline content and membrane stability index (MSI) which are indicative of enhanced drought tolerance. SML-832 had the highest relative water content (RWC), indicating better water retention under limited moisture conditions. Future work should integrate genomic tools to dissect the genetic architecture of these traits, accelerating climate-resilient mungbean breeding.

Conflict of interest

There is no conflict of interest.

Acknowledgment

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Table 1: Details of mungbean genotypes used in investigation

S. No.	Name of genotype	Year of Collection	Source of procurement
Germplasm procured from NBPGR, Regional Station, Jodhpur			
1	IC-39269	1993	Jodhpur, Rajasthan
2	IC-39300	1993	Jaswasar, Bikaner,Rajasthan
3	IC-39328	1993	Lalela, Barmer, Rajasthan
4	IC-39352	1993	Manduwa, Barmer, Rajasthan
5	IC-39399	1993	Jaspura, Palanpur, Gujarat
6	IC-39409	1993	Kapara, Banaskantha, Gujarat
7	IC-39454	1988	Surendranagar, Gujarat
8	IC-39492	1988	Dudhai, Mahesana, Gujarat
9	IC-39608	1992	Nevra, Jodhpur, Rajasthan
10	IC-39610	1992	Osian, Jodhpur, Rajasthan
11	IC-52076	1992	*
12	IC-52081	1992	*
13	IC-52082	1992	*
14	IC-52087	1992	*
15	IC-102792	1986	Banar, Jodhpur, Rajasthan
16	IC-102821	1986	Gidani, Jaipur, Rajasthan
17	IC-102857	1986	Khasur, Dholpur, Rajasthan
18	IC-103014	1986	Alampur, Kheda, Gujarat
19	IC-103059	1986	Krakas, Amreli, Gujarat
20	IC-103244	1986	Bhrwasa, Didwana, Nagaur, Raj.
21	IC-338868	1990	Sanari, Barmer, Rajasthan
Varieties/ genotypes procured from Agriculture University, Jodhpur			
22	Sweta		CSAVAT, Kanpur
23	IPM-02-3		ICAR-IIPR, Kanpur
24	IPM-02-14		ICAR-IIPR, Kanpur
25	Samrat (PDM-139)		ICAR-IIPR, Kanpur
26	GM-4		AAU, Pulse Res.Station,Vadodara
27	MH 2-15		CCSHAU, Hisar
28	MH-421		CCSHAU, Hisar
Varieties/ genotypes procured from RARI, Durgapura, Jaipur			
29	RMG-62		SKRAU-ARS, Durgapura, Jaipur
30	RMG-344		SKRAU-ARS, Durgapura, Jaipur
31	Keshwanand Mung-1 (RMG-975)		SKNAU-RARI, Durgapura, Jaipur
Varieties/ genotypes procured from ARS, Sriganganagar			
32	SML-668		PAU, Ludhiana
33	SML-832		PAU, Ludhiana
34	Ganga-1		SKRAU-ARS, Sriganganagar
35	MUM-2		CCS Meerut University, Meerut

**Source was not mentioned by NBPGR, Regional Station, Jodhpur, Rajasthan..*

Table 2: Analysis of variance of mungbean genotypes for agro-morphological& physio-biochemical traits

S. No.	Character	Sources of variation		
		Replications	Genotypes	Error
	d. f.	2	34	68
1.	Days to 50 per cent flowering	0.009524	23.03473**	0.185994
2.	Days to maturity	0.0381	287.27**	0.71457
3.	Plant height (cm)	22.0247	179.21**	9.60133
4.	Number of pods per plant	1.4381	29.4106**	3.07535
5.	Number of seeds per pod	0.12347	0.45061*	0.13598
6.	Pod length (cm)	0.01766	0.41857**	0.070928
7.	100-seed weight (g)	0.00492	0.39875**	0.00248
8.	Biological yield per plant (g)	2.36	119.15**	3.05
9.	Harvest index (%)	4.88	155.44**	5.00
10.	Chlorophyll-a (mg/g f. w.)	0.00401	0.06421*	0.01798
11.	Chlorophyll-b (mg/g f. w.)	0.00111	0.01634*	0.00312
12.	Total chlorophyll (mg/g f. w.)	0.03279	0.13232*	0.02182
13.	Membrane stability index (%)	0.07433	128.324**	6.54228
14.	Relative water content (%)	7.83283	59.3823*	9.41294
15.	Proline content (mg/g)	0.000087	2.55839**	0.00935
16.	Crude protein content (%)	0.009778	5.02456**	0.02083
17.	Seed yield per plant (g)	0.119238	5.5964**	0.22661

**Significant at P = 0.05, ** Significant at P = 0.01*

Table 3: Genetic variability parameters of mungbean genotypesfor agro-morphological & physio-biochemical traits

S. No.	Characters	Mean	Range		Coefficient of variation		Heritability % (broad sense)	Genetic advance at 5%	Genetic advance as per cent of mean at 5%
			Min.	Max.	Genotypic	Phenotypic			
1.	Days to 50 per cent flowering	43.04	38.00	48.67	6.41	6.44	99.20	5.66	13.16
2.	Days to maturity	74.96	64.00	95.00	13.04	13.05	99.80	20.11	26.82
3.	Plant height (cm)	50.54	32.38	62.32	14.88	15.29	94.60	15.07	29.82
4.	Number of pods per plant	24.98	19.67	33.33	11.86	12.53	89.50	5.78	23.12
5.	Number of seeds per pod	9.4	8.72	10.20	3.45	4.12	69.80	0.56	5.93
6.	Pod length (cm)	7.46	6.78	8.63	4.56	5.01	83.10	0.64	8.56
7.	100-seed weight (g)	4.16	3.55	5.34	8.73	8.76	99.40	0.75	17.93
8.	Biological yield per plant (g)	29.76	17.10	47.36	20.91	21.18	97.40	12.65	42.51
9.	Harvest index (%)	35.73	22.95	48.28	19.82	20.15	96.80	14.35	40.17
10.	Chlorophyll-a (mg/g f. w.)	2.05	1.59	2.38	6.05	7.13	72.00	0.22	10.58
11.	Chlorophyll-b (mg/g f. w.)	0.64	0.46	0.81	10.30	11.45	80.90	0.12	19.08
12.	Total chlorophyll (mg/g f. w.)	2.69	2.05	3.17	7.13	7.80	83.50	0.36	13.42
13.	Membrane stability index (%)	54.55	38.19	63.89	11.68	11.99	94.90	12.79	23.44
14.	Relative water content (%)	71.75	52.09	76.81	5.69	6.20	84.10	7.71	10.75
15.	Proline content (mg/g)	3.07	1.11	5.08	30.06	30.11	99.60	1.90	61.80
16.	Protein content (%)	23.52	21.03	25.23	5.49	5.50	99.60	2.66	11.29
17.	Seed yield per plant (g)	9.34	6.99	13.14	14.33	14.63	96.00	2.70	28.91

Table 4: Mean performance of genotypes for agro- morphological & physio-biochemical traits over environments

S. NO.	Name of genotype	DF	DM	PH (cm)	Number of pods per plant	Number of seeds per pod	PL (cm)	100-SW (g)	BY (g)	HI (%)	Chl.-a (mgg^{-1} f. w.)	Chl.-b (mgg^{-1} f. w.)	Total Chl. (mgg^{-1} f. w.)	MSI (%)	RWC (%)	Proline content (mgg^{-1} f. w.)	Protein content (%)	Seed yield per plant (g)
1.	IC-39269	43.33	75.00	62.32	27.33	9.47	7.43	4.06	30.30	36.85	2.29	0.80	3.09	59.22	65.61	2.83	24.13	10.44
2.	IC-39300	41.00	94.00	59.25	22.00	9.70	7.31	4.15	34.57	26.44	2.14	0.68	2.82	51.98	74.88	3.73	21.18	7.86
3.	IC-39328	40.00	81.66	51.45	28.67	9.27	7.37	3.70	30.80	32.52	2.15	0.68	2.84	61.46	73.18	2.82	21.77	9.36
4.	IC-39352	41.33	81.33	48.03	24.00	8.75	6.78	4.09	29.05	33.15	2.01	0.64	2.65	48.94	72.28	3.18	21.03	8.48
5.	IC-39399	44.67	77.33	60.28	24.67	8.77	6.99	4.15	37.00	27.79	2.07	0.62	2.69	56.65	72.53	2.65	21.38	8.52
6.	IC-39409	43.00	66.00	51.18	20.67	10.20	7.69	4.10	30.53	32.48	2.22	0.76	2.97	57.41	64.47	3.79	21.23	8.32
7.	IC-39454	43.33	74.00	53.80	24.00	8.98	7.20	4.32	31.22	30.15	2.01	0.60	2.61	56.76	71.76	2.71	21.52	8.37
8.	IC-39492	42.67	72.00	55.67	29.67	9.27	7.48	4.31	38.40	31.93	2.18	0.66	2.83	55.17	68.83	2.52	22.35	11.36
9.	IC-39608	46.67	87.00	57.28	23.33	9.54	7.27	3.90	35.05	27.15	2.06	0.63	2.69	42.55	68.52	2.28	24.33	7.90
10.	IC-39610	45.67	91.66	53.53	23.33	9.41	7.51	4.03	34.57	25.89	1.88	0.57	2.44	55.03	71.38	2.80	24.23	8.01
11.	IC-52076	47.67	83.66	54.20	21.67	10.02	7.25	3.55	32.52	28.39	2.08	0.67	2.75	51.48	73.36	3.77	25.23	7.40
12.	IC-52081	41.00	65.00	34.32	19.67	10.07	7.71	3.98	17.10	48.28	2.08	0.67	2.75	38.19	76.55	5.08	24.70	8.03
13.	IC-52082	48.67	86.66	52.52	24.00	9.72	7.27	3.82	33.30	31.26	2.11	0.66	2.76	58.00	76.14	3.01	25.17	8.63
14.	IC-52087	42.33	66.00	32.38	22.33	10.10	7.64	3.72	21.57	42.13	1.91	0.60	2.51	63.24	72.19	4.96	22.46	8.85
15.	IC-102792	46.00	94.00	56.80	23.67	9.63	7.08	4.07	38.40	26.63	1.86	0.60	2.46	63.89	75.55	2.11	23.58	8.49
16.	IC-102821	45.00	74.66	59.95	27.00	9.36	7.13	3.90	36.47	35.10	2.15	0.70	2.85	49.75	74.40	3.05	23.33	10.28
17.	IC-102857	47.00	83.00	57.70	27.67	8.99	7.34	4.16	34.57	33.76	1.97	0.56	2.53	49.78	71.05	1.91	24.88	10.12
18.	IC-103014	44.00	70.00	58.12	23.67	9.57	7.43	4.11	28.17	38.49	2.03	0.65	2.67	59.87	71.25	1.39	24.51	9.26
19.	IC-103059	44.67	78.66	57.43	25.00	9.27	7.32	4.18	28.25	36.75	2.38	0.80	3.17	56.23	72.23	3.01	23.46	9.43
20.	IC-103244	46.67	84.33	55.17	21.00	9.10	7.58	4.10	31.60	25.48	2.12	0.65	2.76	49.89	74.67	1.11	24.70	6.99
21.	IC-338868	48.67	95.00	61.68	24.33	9.23	7.38	4.16	47.36	22.95	2.21	0.70	2.90	61.44	70.06	3.08	22.27	9.09
22.	Sweta	39.67	64.00	35.60	23.33	8.90	7.67	4.02	18.12	48.24	1.81	0.53	2.33	63.89	69.95	4.34	23.36	8.26
23.	IPM-02-3	39.00	70.00	41.87	23.00	8.72	8.63	5.34	20.75	45.65	2.00	0.59	2.59	59.60	74.78	3.50	23.68	9.39
24.	IPM-02-14	40.67	67.00	42.88	23.33	8.95	7.99	4.77	19.82	46.88	1.99	0.81	2.80	61.47	71.26	3.10	24.21	8.88
25.	Samrat (PDM-139)	42.33	69.66	47.15	24.33	9.10	7.74	4.61	24.27	39.96	2.13	0.67	2.80	56.95	69.89	3.51	23.30	9.70
26.	GM-4	38.00	64.00	46.30	27.00	9.44	8.06	5.15	28.13	47.43	2.09	0.60	2.69	58.83	76.16	3.30	24.77	13.14
27.	MH 2-15	41.33	66.00	46.38	25.33	9.45	7.32	4.18	25.53	38.04	2.07	0.61	2.68	46.92	71.52	2.00	23.44	9.72
28.	MH-421	40.00	66.33	42.72	22.33	9.38	7.68	4.51	23.43	41.34	2.19	0.67	2.86	49.32	75.47	1.95	24.90	9.01
29.	RMG-62	41.00	67.33	47.52	29.67	9.55	7.11	4.22	27.23	43.38	2.02	0.57	2.59	60.83	74.52	2.83	22.99	11.40
30.	RMG-344	42.00	68.00	48.22	33.33	9.39	6.99	3.83	31.73	39.34	1.99	0.59	2.59	51.54	72.80	3.00	23.93	12.07
31.	Keshwanand Mung-1	41.00	67.33	50.90	31.33	9.80	7.25	3.83	30.93	34.86	1.85	0.60	2.45	59.09	72.15	3.60	22.52	10.69
32.	SML-668	42.33	64.00	48.37	22.00	9.70	7.53	4.28	28.27	33.30	2.09	0.65	2.74	49.46	70.79	4.66	24.96	8.65
33.	SML-832	41.67	66.00	41.13	28.33	9.60	8.33	4.27	27.93	39.49	2.00	0.61	2.61	55.26	76.81	4.40	24.96	11.13
34.	Ganga-1	43.00	76.00	49.07	26.33	8.98	7.41	4.02	27.50	35.05	2.05	0.69	2.74	47.94	72.21	2.98	24.80	9.13
35.	MUM-2	41.00	67.00	47.72	27.00	9.53	7.29	4.11	27.03	43.94	1.59	0.46	2.05	41.25	52.09	2.38	23.91	10.44
Overall mean		**43.04**	**74.96**	**50.54**	**24.98**	**9.40**	**7.46**	**4.16**	**29.76**	**35.73**	**2.05**	**0.64**	**2.69**	**54.55**	**71.75**	**3.07**	**23.52**	**9.34**
Range		38.00-48.67	64.00-95.00	32.38-62.32	19.67-33.33	8.72-10.20	6.78-8.63	3.55-5.34	17.10-47.36	22.95-48.28	1.59-2.38	0.46-0.81	2.05-3.17	38.19-63.89	52.09-76.81	1.11-5.08	21.03-25.23	6.99-13.14
SE m ±		0.25	0.48	1.79	1.01	0.21	0.15	0.03	1.01	1.29	0.08	0.03	0.09	1.48	1.77	0.06	0.08	0.27
CD (5%)		0.70	1.37	5.05	2.86	0.60	0.43	0.08	2.85	3.64	0.22	0.09	0.24	4.17	5.00	0.16	0.24	0.78
CD (1%)		0.93	1.82	6.70	3.79	0.80	0.58	0.11	3.78	4.84	0.29	0.12	0.32	5.53	6.64	0.21	0.31	1.03
CV (%)		1.00	1.12	6.13	7.02	3.92	3.57	1.20	5.87	6.26	6.54	8.67	5.48	4.69	4.28	3.15	0.61	5.10

DF= Days to 50 per cent flowering; DM= Days to maturity; PH = Plant height; PL = Pod length; 100-SW = 100 seed weight; BY= Biological yield per plant; HI = Harvest Index; Chl.-a = Chlorophyll-a; Chl.-b = Chlorophyll-b; Total Chl. = Total Chlorophyll; MSI = Membrane stability index; RWC = Relative water content.

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