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RESEARCH ARTICLE

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Evaluation of Mungbean Mini Core Collection for Yield-Related and Seed Quality Traits

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ABSTRACT

Background: Mungbean serves as a chief source of dietary protein (22–28%), playing a vital role in alleviating malnutrition. Mungbean has a yield potential of 2.5-3.0 t/ha; however, the average yield remains significantly low due to various biotic and abiotic constraints, suboptimal crop management practices and the limited availability of quality seeds of improved varieties. The World Vegetable Center, Taiwan, holds one of the largest collections of mungbean accessions, which serves as a valuable resource for crop improvement.
Methods: The mungbean mini core collection (MMC), comprising 293 accessions of diverse origin obtained from World Vegetable Center was evaluated for yield and yield related traits during the 2023/24 and 2024/25 rainy season in alpha lattice design.
Result: The study revealed significant (p<0.001) variation for yield and related traits. Among the accession VI003951 AG was the earliest flowering (31 days) and maturing in 59 days after sowing. The accession VI001244 AG recorded a 100-seed weight of more than 8.60 grams. In the GGE biplot analysis, accessions VI001728 AG (94), VI002432 AG (121), VI003019 BG (149), VI003886 BY (220) and VI003954 BG (233) were identified as the most stable genotypes and the accessions VI000461 BG (17) and VI004811 BG (270) as top performers during 2023/24 (E1), while VI000232 AG (10) and VI001400 AG (61) performed best during 2024/25 (E2). The green color (238 accessions) shiny seed lustre (158 accessions) and purple hypocotyls (244 accessions) were dominant in the MMC set. Overall, the study provides valuable insights for selecting superior and stable genotypes for mungbean improvement.

Key words: Correlation, GGE biplot, Mungbean, Stability, Yield.

INTRODUCTION

Mungbean [*Vigna radiata* (L.) R. Wilczek var. *radiata*] is commonly known as green gram is an important grain legume crop grown in south Asia, south east Asia and Australia (Kitsanachandee *et al*., 2013; Azam *et al*., 2023). Over 70 per cent of the global mungbean cultivation area is distributed across India, Myanmar, Pakistan and Bangladesh (Nair and Schreinemacher, 2020; Alam *et al* 2014). Mungbean seeds are cheap and primary source of carbohydrates and dietary protein (22-28%) thus plays a vital role in alleviating malnutrition (Hou *et al*., 2019; Dahiya *et al*., 2015; Wang *et al*., 2021; Keatinge *et al*., 2011; Nair *et al*., 2019; Somta *et al*., 2022).

The World Vegetable Center, Taiwan holds one of the largest collections of mungbean germplasm. The mungbean mini core collection (MMC) represents 4% of the total collection and serves as a valuable resource for trait discovery and crop improvement (Schafleitner *et al*., 2015; Breria *et al*., 2020). Mungbean has a yield potential of 2.5-3.0 t/ha; however, the average yield remains significantly low (721 kg/ha) due to various biotic and abiotic constraints, suboptimal crop management practices and the limited availability of quality seeds of improved varieties (Nair *et al*., 2019; Akram *et al*., 2024; Nair and Schreinemacher, 2020). The present study aimed to evaluate MMC for yield and yield related traits. The findings will support breeding programs in developing improved mungbean varieties.

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MATERIALS AND METHODS

Plant material and location

The mungbean mini core collection (MMC) consists of 293 accessions developed from 6,742 accessions have diverse origin (Schafleitner *et al*., 2015). Field evaluations for agronomic performance was conducted at the World Vegetable Center, South Central Asia, Hyderabad (17.50209°N, 78.27646°E; elevation 550 m).

Evaluation for MMC for yield and yield related traits

The MMC set was evaluated for yield and related traits during the rainy seasons (July-September) of 2023/24 and 2024/25. The field design was laid out in an alpha lattice design with two replications, following a spacing of 45 ×10 cm, with each accession planted in a single row of 2 meters in length. Five plants were randomly selected from each plot and the data was recorded for the traits as described in the Table 1.

Data analysis

Analysis of variance (ANOVA) was performed to test the significance of the agronomic traits. GGE biplots were constructed using the “METAN” package in R software (version 2024.12.1+563).

RESULTS AND DISCUSSION

Evaluation of MMC for yield and related traits

The 293 accessions of MMC evaluated for traits such as DFF, DTM, PHT, PPP, CPP, PLT SPP, HSW and YPP exhibited significant variability (p<0.001) among the accessions (Table 2). There are six different seed coat color variations were observed. Seed lustre ranged from shiny to dull and a mixed appearance. The hypocotyl color varies from green to purple. Similar variation in both quantitative and qualitative traits has been observed in 482 accessions of the Iowa mungbean panel (Sandhu and Singh, 2021).

a) Days to 50% flowering (DFF), maturity (DTM) and plant height (PHT)

The DFF across the accessions ranged from 31 to 52 days, whereas maturity ranged from 59 to 82 days after sowing (DAS) with PHT ranging from 31.75 cm to 88.43 cm. The VI003951 AG was the earliest flower (31 days) and maturing in 59 days after sowing (Table 3). Whereas accession VI004743 AG recorded maximum PHT (88.43 cm) and VI004666 AG is shortest (31.75 cm). Correlation analysis revealed a moderate positive association (r = 0.39) between DFF and DTM suggesting that delayed flowering is generally associated with delayed maturity (Fig 1). The wide variation in flowering and maturity days among the accessions is attributed to genetic diversity and influenced by environmental conditions. Similar variation in the DFF, DTM and PHT has been observed in the mungbean germplasm (Azam *et al*., 2023; Kanavi *et al*. 2020; Win *et al*., 2020; Muthuswamy *et al*. (2019).

b) Clusters per plant (CPP), pods per plant (PPP) and pod length (PLT)

The number of CPP, PPP and PLT showed significant variation (p<0.001) among accessions (Table 2). The highest number of PPP was recorded in accession VI001728 AG (mean = 61.48), which produced ten clusters and with an average pod length of 6.85 cm (Table 3). Accession VI002063 BG exhibited the longest PLT (10.35 cm), but showed less PPP (10.44) and CPP (3.83). A strong positive correlation (r = 0.78) was observed between CPP and PPP, indicating that an increase in cluster number is closely associated with a higher number of pods (Fig 1). Similar observations of differences in the PPP ranging from 4.38 to 35.72 was observed in a set of 200 mungbean accessions (Kanavi *et al*., 2020).

d) Seeds per pod (SPP) and 100 seed weight (HSW)

The highest SPP was recorded in accession VI002063 BG (15.70), followed by VI000232 AG (14.60). Whereas highest HSW was recorded in accession VI001244 AG (8.66 g). Correlation analysis revealed a weak positive relationship (r = 0.13) between SPP and HSW (Fig 1), indicating that the number of SPP has minimal influence on HSW. The SPP was found to be determined by additive gene action (Dikshit *et al*., 2020). Similar observations of differences in the SPP ranging from 3.07 to 9.70 was observed in mungbean accessions (Kanavi *et al*., 2020).

e) Yield performance of MMC through GGE biplot analysis

In a GGE biplot analysis, first two principal components (PC1 and PC2) explained 70.56% and 29.44% of the total variation respectively. In the “mean vs. stability” view,

Table 1: Description of traits used for evaluating mungbean mini core collection.

Trait	Acronym	Description
Seed color	SC	1=green; 2=black; 3=brown; 4=yellow; 5=speckled/mottle; 6=mixed
Seed lustre	SL	A=shiny; B=dull; AB=mixed
Hypocotyl color	HC	1=purple; 2= green
Days to 50% flowering	DFF	Number of days from sowing to the stage when 50% plants have begun flowering
Days to maturity	DTM	Number of days from sowing to 90% pods matured or turned black
Plant height	PHT	Average canopy height (cm) of 5 plants at the end of the flowering
Pods per plant	PPP	Average number of pods of 5 plants
Clusters per plant	CPP	Number of pods per cluster, 5 random plants
Pod length	PLT	Pod Length in cm, 5 random plants 2 pods per plant
Seeds per pod	SPP	Average of 10 pods each from 5 plants
100 seed weight	HSW	Weight of 100 seeds in grams
Seed yield per plant	SYP	Average seed yield per plant (grams) from 5 plants

genotypes positioned further to the right along the average environment axis (AEA) exhibited higher mean yields, with accessions 230 (VI003947 B-BR), 52 (VI001191 BG) and 182 (VI003440 AG) showing superior average performance. The accessions 94 (VI001728 AG), 121 (VI002432 AG), 149 (VI003019 BG), 220 (VI003886 BY) and 233 (VI003954 BG) were among the most stable genotypes (Fig 2a). In the "which-won-where" polygon view, accessions 17 (VI000461 BG) and 270 (VI004811 BG) were better performing in environment E1 (2023), whereas accessions 10 (VI000232 AG) and 61 (VI001400 AG) were identified as the top performer under the conditions of E2 (2024) (Fig 2b). The PPP had a strong positive correlation with YPP (r = 0.77), indicating that an increase in the number of PPP significantly contributes to higher yield (Fig 1) which is in agreement with the observations recorded by Priya and Babu (2024). Similar variation in mungbean yield performance across diverse germplasm collections were also reported by Das *et al*. (2024), aligning with the finding of the present study. Temperature and photoperiod are key environmental factors that influence the phenological development of mungbean in all growth stages and thus determine yield and adaptability (Somta *et al*., 2022). The seed yield is complex trait controlled by several genes with additive effect and mode of inheritance varies with parent genotype (Dikshit *et al*., 2020). Ullah *et al*. (2012) was found similar observation though GGE analysis suggesting genotypic and environmental influence on final yield of mungbean genotypes.

Table 2: Range of traits, their heritability and pooled two-way ANOVA for agronomic traits (yield and related traits).

Trait	Range	Heritability	Source	Pr (>F)	Level of significance
			Accession	4.83^{E-119}	***
DFF	31-52 days	0.51	Year	3.54^{E-75}	***
			Replication	0.4903	NS
			Accession: Year	1.01^{E-77}	***
			Accession	2.67^{E-110}	***
DTM	59-82 days	0.35	Year	1.07^{E-171}	***
			Replication	0.5014	NS
			Accession: Year	7.01^{E-66}	***
			Accession	3.88^{E-236}	***
PHT	31.75-88.43 cm	0.68	Year	1.95^{E-138}	***
			Replication	0.9170	NS
			Accession: Year	3.08^{E-132}	***
			Accession	1.78^{E-250}	***
PPP	5.80- 61.48 no.	0.17	Year	0.00	***
			Replication	0.0030	**
			Accession: Year	1.29^{E-213}	***
			Accession	1.64^{E-60}	***
CPP	1.40-14.50 no.	0.21	Year	1.29^{E-127}	***
			Replication	0.01402	*
			Accession: Year	4.42^{E-46}	***
			Accession	6.98^{E-95}	***
PLT	5.60-10.35 cm	0.72	Year	4.28^{E-09}	***
			Replication	0.0771	NS
			Accession: Year	1.22^{E-06}	***
			Accession	5.28^{E-44}	***
SPP	9.10- 15.70 no.	0.50	Year	1.19^{E-06}	***
			Replication	0.5570	NS
			Accession: Year	8.04^{E-10}	***
			Accession	1.00^{E-239}	***
HSW	1.26-8.66 g	0.75	Year	1.49^{E-110}	***
			Replication	0.7481	NS
			Accession: Year	1.15^{E-104}	***
			Accession	1.60^{E-221}	***
YPP	2.96-31.71 g	0.32	Year	0.00	***
			Replication	0.03128	*
			Accession: Year	2.71^{E-164}	***

*** Highly significant; ** Very significant; * Significant; NS= Non-significant.

Table 3: Selected high-performing mungbean accessions based on yield and yield related traits during rainy season 2023/24 and 2024/25.

Accession No.	Accession name	Origin	Seed color	Seed lustre	Hypocotyl color	DFF	DTM	PHT	PPP	CPP	PLT	SPP	HSW	YPP
Days to 50% flowering (DTF)														
64	VI001408 BG	India	1	AB	Purple	31	64	50.05	23.20	6.95	6.91	11.91	4.65	14.29
231	VI003948 B-BR	India	3	B	Purple	31	60	35.20	17.16	5.95	6.00	10.80	4.52	8.17
232	VI003951 AG	India	1	A	Purple	31	59	40.75	16.35	5.55	8.43	12.79	4.10	10.92
Days to maturity (DTM)														
232	VI003951 AG	India	1	A	Purple	31	59	40.75	16.35	5.55	8.43	12.79	4.10	10.92
197	VI003563 A-BR	India	1	A	Green	34	59	64.25	26.10	8.30	6.83	12.00	5.72	17.87
202	VI003658 BG	India	1	B	Green	34	59	67.75	44.70	10.30	6.50	10.10	4.05	18.29
293	VI005030 BY	Mexico	4	A	Green	34	59	57.25	12.20	4.50	8.30	11.80	3.60	5.19
173	VI003276 BG	India	1	B	Purple	37	59	66.35	17.00	7.30	6.84	12.45	3.31	6.93
Plant height (PHT)														
262	VI004666 AG	Iran	3	A	Purple	35	64	31.75	25.30	7.05	6.75	12.10	4.52	14.26
137	VI002802 A-BR	Iran	3	A	Purple	37	67	34.14	24.75	8.38	6.53	12.00	5.18	15.16
117	VI002239 AG	Afghanistan	3	A	Purple	36	65	34.43	17.63	5.60	6.65	12.50	3.23	7.43
87	VI001628 AG	India	1	A	Purple	35	64	34.55	23.60	7.35	6.85	11.25	3.10	8.88
Pods per plant (PPP)														
94	VI001728 AG	India	1	A	Purple	39	64	67.75	61.48	10.00	6.85	11.65	4.18	29.86
75	VI001520 A-BLM	India	5	A	Purple	36	61	74.60	53.00	13.40	6.95	13.40	4.46	31.71
202	VI003658 BG	India	1	B	Green	34	59	67.75	44.70	10.30	6.50	10.10	4.05	18.29
24	VI000559 AG	India	1	A	Purple	39	70	72.15	40.70	9.85	6.93	11.85	6.46	31.03
16	VI000380 AG	Philippines	1	A	Purple	43	65	70.10	40.23	9.95	7.73	12.85	4.68	26.48
Clusters per plant (CPP)														
61	VI001400 AG	India	1	A	Purple	38	65	75.33	35.25	14.50	7.40	12.20	5.83	26.77
75	VI001520 A-BLM	India	5	A	Purple	36	61	74.60	53.00	13.40	6.95	13.40	4.46	31.71
19	VI000532 BG	India	1	A	Purple	46	69	65.20	40.00	12.15	7.35	12.55	4.43	21.10
Pod length (PLT)														
108	VI002063 BG	USA	1	B	Purple	37	71	50.08	10.40	3.83	10.35	15.70	7.50	12.15
18	VI000470 AG	Pakistan	1	AB	Purple	43	66	48.18	10.60	3.95	9.96	12.10	6.63	8.64
1	VI000020 AY	Thailand	4	A	Purple	38	61	54.85	28.40	6.90	9.44	12.80	6.03	21.85
55	VI001244 AG	Philippines	1	A	Purple	45	66	60.83	14.25	4.95	9.27	11.65	8.66	14.36
54	VI001221 AG	Philippines	1	AB	Purple	39	62	56.60	16.43	6.18	9.18	12.55	5.75	12.23
Seeds per pod (SPP)														
108	VI002063 BG	USA	1	B	Purple	37	71	50.08	10.40	3.83	10.35	15.70	7.50	12.15
10	VI000232 AG	Iran	1	A	Purple	41	73	61.40	28.20	8.60	8.88	14.60	5.96	24.52
34	VI000736 AG	India	1	A	Green	35	65	61.35	16.90	5.40	8.46	13.70	4.09	9.73

Table 3: Continue....

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284	VI004956 AG	Pakistan	1	A	Purple	36	63	66.20	23.40	6.75	8.14	13.45	4.08	13.40
48	VI001096 AG	Australia	1	A	Purple	42	68	52.50	11.55	4.90	8.88	13.40	5.30	8.39
40	VI000818 BG	India	1	B	Purple	36	64	47.50	20.90	6.10	7.75	13.40	6.13	17.41
75	VI001520 A-BLM	India	5	A	Purple	36	61	74.60	53.00	13.40	6.95	13.40	4.46	31.71
100 seed weight (HSW)														
55	VI001244 AG	Philippines	1	A	Purple	45	66	60.83	14.25	4.95	9.27	11.65	8.66	14.36
60	VI001385 AG	India	1	A	Green	39	74	54.10	10.30	3.70	6.48	11.60	8.07	9.66
136	VI002739 AG	Iran	1	A	Purple	38	61	54.03	16.65	7.10	6.50	11.70	7.83	15.26
49	VI001124 AG	Australia	1	A	Purple	35	63	65.60	13.65	4.50	8.10	12.20	7.63	12.73
108	VI002063 BG	USA	1	B	Purple	37	71	50.08	10.40	3.83	10.35	15.70	7.50	12.15
121	VI002432 AG	Thailand	1	B	Purple	44	63	42.70	16.80	8.25	8.75	12.90	7.47	16.19
Yield per plant (YPP)														
75	VI001520 A-BLM	India	5	A	Purple	36	61	74.60	53.00	13.40	6.95	13.40	4.46	31.71
24	VI000559 AG	India	1	A	Purple	39	70	72.15	40.70	9.85	6.93	11.85	6.46	31.03
94	VI001728 AG	India	1	A	Purple	39	64	67.75	61.48	10.00	6.85	11.65	4.18	29.86
61	VI001400 AG	India	1	A	Purple	38	65	75.33	35.25	14.50	7.40	12.20	5.83	26.77
17	VI000461 BG	Thailand	1	B	Purple	40	65	65.20	39.98	7.75	7.85	12.55	5.32	26.63
16	VI000380 AG	Philippines	1	A	Purple	43	65	70.10	40.23	9.95	7.73	12.85	4.68	26.48

Seed color, 1=green; 2=black; 3=brown; 4=yellow; 5=speckled/mottle; 6=mixed. Seed lustre, A=shiny; B=dull; AB=mixed.

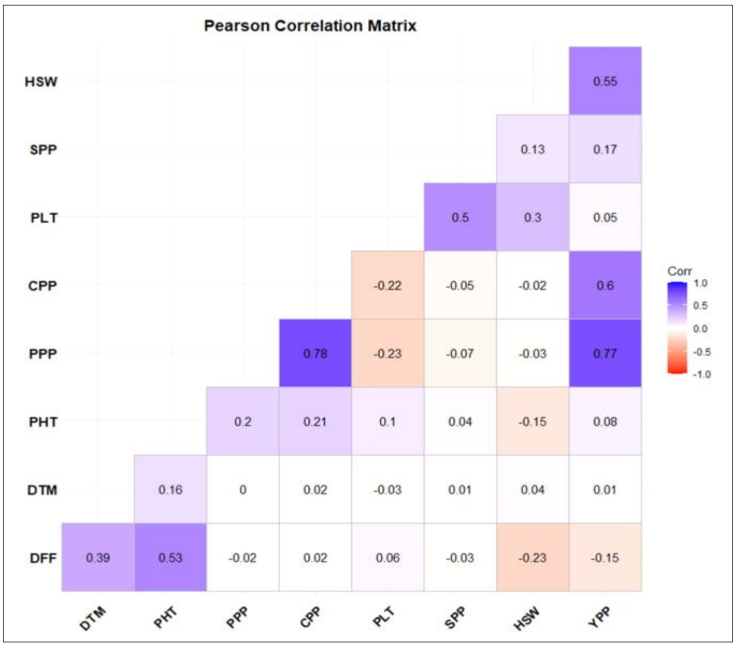

Fig 1: Pairwise Pearson correlation coefficients between key agronomic traits in mungbean mini core accessions evaluated across two years.

f) Broad-sense heritability estimates for yield and yield-related traits

Heritability (broad sense) varied across the traits, indicating differential genetic control and environmental influence. High heritability was observed for HSW (0.75) and PLT (0.72), suggesting that these traits are largely governed by genetic factors and can be effectively improved through selection. PHT also exhibited moderately high heritability (0.68), indicating good scope for selection. Moderate heritability was recorded for days to DFF (0.51) and SPP (0.50), indicating a fair proportion of genetic control, although environmental influence cannot be overlooked. In contrast, DTM (0.35), YPP (0.32), CPP (0.21) and PPP (0.17) exhibited low heritability (Table 2), suggesting that these traits are more influenced by the environment and selection based on phenotype may be less effective. In contrast, Sawarkar *et al*. (2025) reported high broad-sense heritability for seed yield per plant (0.95) and number of pods per plant (0.94), highlighting potential differences in genetic background. Akhtar *et al*. (2021) observed that 100 seed weight is the one of the most significant yield contributing traits in mungbean less affected by the environment. These observations are in line with the findings of Jain *et al*. (2024) and Rahangdale *et al*. (2023).

g) Qualitative parameter- seed color, seed lustre and hypocotyl color

The MMC set comprised of green seed (238), brown (26), mottled/speckled (12), yellow (5), black (2) and mixed (10) seed coat colours. Seed lustre varied from shiny (158) to dull (124) and mixed (11) (Fig 3). Two hypocotyl colours were observed; purple (244) and green (49). These qualitative seed traits are important for targeting region-

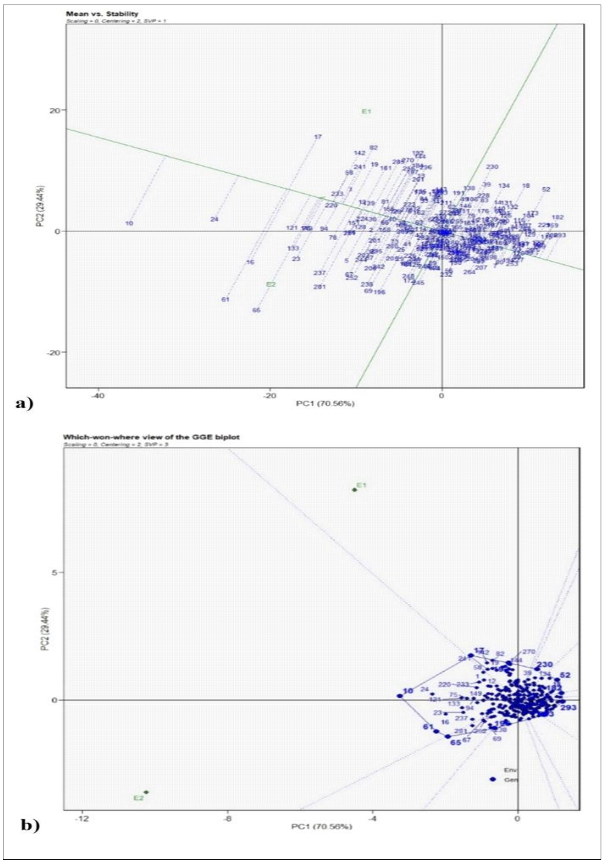

Fig 2: Mean vs stability GGE biplot for grain yield of mungbean mini core accessions (a); Which won-where view of GGE biplot for grain yield of 293 mungbean mini core accessions (b). E1=2023 and E2=2024.

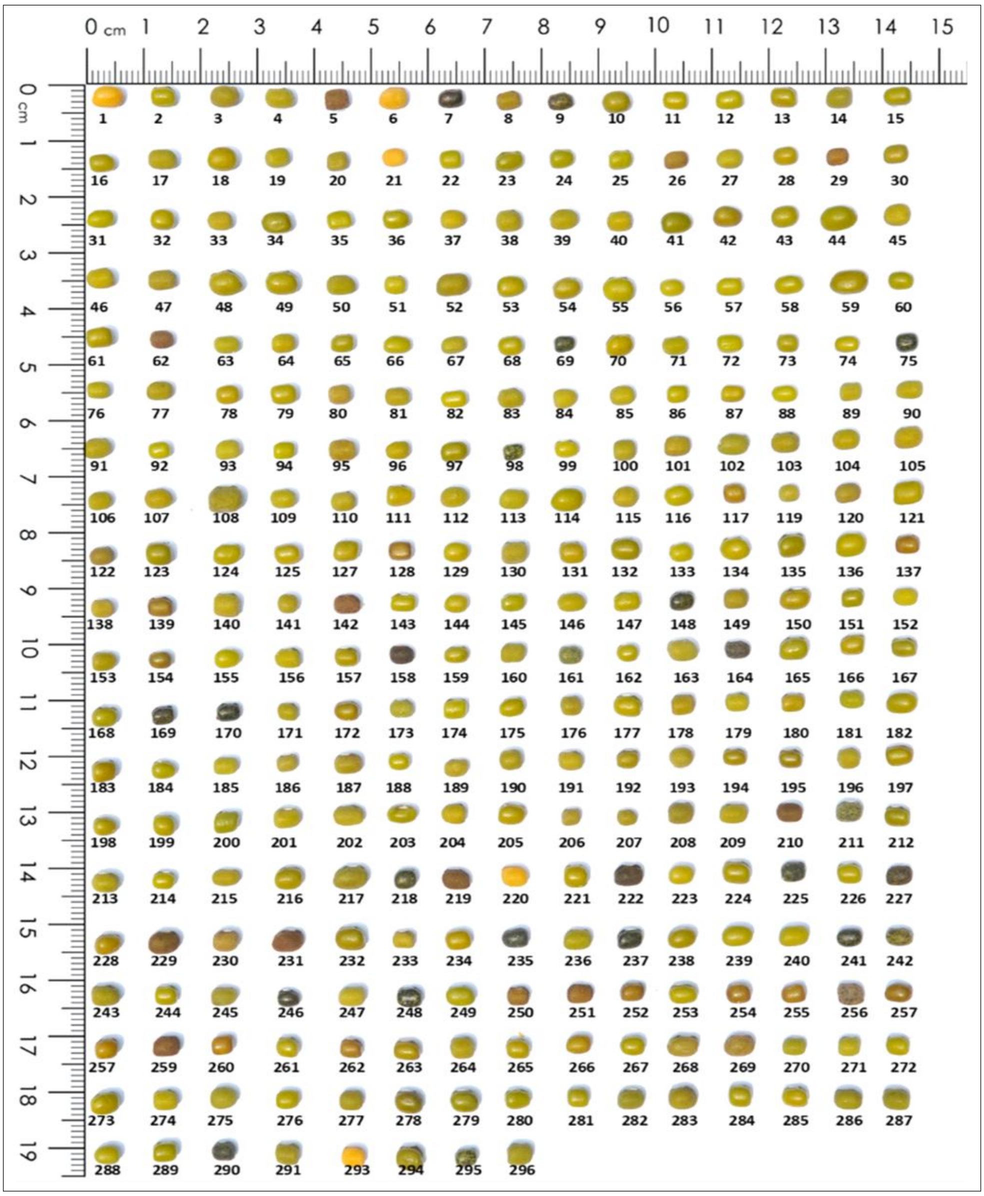

Fig 3: World Vegetable Center's mungbean mini core accessions (293) showing diversity in seed color, size and their lustre.

specific preferences. For example, yellow seed coat mungbean (commonly known as *Sona mung*) are traditionally cultivated in Bhutnir Char region of West Bengal and in certain regions of Bangladesh and Sri Lanka (Brahmachary and Ghosh, 2000; Pal *et al*., 2010; Mung Central, 2020). Similarly, brown seed coat mungbean variety TARI Gram II has been released by the Tanzania Agricultural Research Institute (TARI, 2022). Whereas shiny green mungbean varieties are the most preferred segment across the Indian subcontinent (Mung Central, 2020). Additionally, hypocotyl color plays a crucial role in the sprouting industry, *e.g*: AVMU 1688 resistance to mungbean yellow mosaic disease (MYMD) suitable for sprouting market has been recently released in Myanmar (Aung *et al*., 2024).

CONCLUSION

The mungbean mini core collection consists of highly diverse and heterozygous germplasm and serves as a source of material for improvement of several quantitative and qualitative traits. Notably, accession VI003951 AG was the earliest to mature (59 days). The accessions VI001728 AG showed the highest PPP, averaging 61.48 pods. Additionally, accession VI001244 AG recorded an HSW of more than 8.60 grams, making it a potential source for improving seed size. Based on the GGE biplot analysis, accessions 230 (VI003947 B-BR), 52 (VI001191 BG) and 182 (VI003440 AG) showing superior average performance and accessions 94 (VI001728 AG), 121 (VI002432 AG), 149 (VI003019 BG), 220 (VI003886 BY) and 233 (VI003954 BG) were among the most stable genotypes, making them promising candidates for further evaluation and inclusion in mungbean breeding programs.

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Ethics and permissions

Not applicable.

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Conflict of interest

The authors declare that there is no conflict of interest.

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