RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 59 Issue 10: 1502-1509 (October 2025)

Genetic and Phenotypic Insights into Seed Characteristics for Enhancing Yield Potential in Mungbean [*Vigna radiata* (L.) Wilczek]

Anil Kumar[1], N.K. Sharma[2], Anita[3], Komal Shekhawat[1], Swarnlata Kumawat[1]

10.18805/IJARe.A-6330

ABSTRACT

Background: The study investigates the genetic variability, heritability and character association among seed characteristics in mungbean genotypes. Mungbean is an important pulse crop and understanding its genetic diversity is crucial for breeding programs aimed at improving seed traits such as size, weight and yield. This research employs statistical analyses to evaluate the extent of genetic variability and to explore the relationships between various seed characteristics.

Methods: In this field-laboratory investigation, field experiments were conducted with 35 mungbean genotypes over four environments created by four different dates of sowing in Randomized Block design (RBD) with three replications at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan during summer-2019, *Kharif*-2019 and *Kharif*-2020.

Result: Highly significant differences were found among all genotypes for all seed traits studied. The high degree of genetic variability along with high heritability and high genetic advance as per cent of mean were observed for water absorption capacity, water absorption index and porosity which reveals that these characters were under the control of additive gene action and therefore, form the basis of selection for mungbean improvement programme. Among seed traits, water absorption index and 100-seed weight had positive correlation with seed yield and directly contributed towards seed yield.

Key words: Genetic variability, Heritability, Mung bean, Phenotypic association, Seed characteristics.

INTRODUCTION

Pulses are an important source of staple protein for vegetarians which constitute a major population of the country. Mungbean is also known as green gram, an ancient pulse crop widely cultivated under different agro-ecological situations in India mainly during *Kharif* and summer seasons (Kumar *et al.,* 2024). It is a diploid species having chromosome number (2n=22) belongs to family Leguminosae (Fabaceae), sub-family Papilionaceae and is botanically recognized as *Vigna radiata* (L.) Wilczek (Anita *et al.,* 2022). Mungbean is a native of South Asia (India). *Vigna radiata* var. *sublobata* is the possible progenitor of mungbean. It is basically a self-pollinated crop (Singh *et al.*, 2015).

After chickpea and pigeon pea in terms of production and area, mungbean is the third most significant pulse crop in India. India is a major producer of mungbean and at the same time India identified as the largest consumer of mungbean in the world (Sneha *et al*., 2020). In India, the total area covered under mungbean is 4.607 million hectares with a production of 2.448 m tons and a productivity of 513 kg/ha in the country during 2017-18 to 2021-2022 (Directorate of Pulses Development, 2022). Currently, the realized average productivity of mungbean is well below the economic level (Rahmianna *et al*., 2021).

Pulses play an important role in supplying the needs of food in human society, especially in developing countries. Determination of physical and mechanical properties of seeds and agricultural products is important in designing of harvesting, handling and processing equipment, transport, yield and store of the crop. Physical parameters of seed affect vegetative growth and are frequently related to yield, market grade and harvest efficiency. Some physical properties of seeds *viz*., 100-seed weight, seed volume and seed size are the important characteristics for designing equipment for the transportation of agricultural produce (Peleg, 1985). Genetic variation is the cause forvariation in the size of seed between varieties. Many

[1]Department of Genetics and Plant Breeding, College of Agriculture, Bikaner Swami Keshwanand Rajasthan Agricultural University, Bikaner-334 006, Rajasthan, India.

[2]Department of Genetics and Plant Breeding, Swami Keshwanand Rajasthan Agricultural University, Bikaner-334 006, Rajasthan, India.

[3]Department of Genetics and Plant Breeding, Sri Karan Narendra College of Agriculture, Sri Karan Narendra Agriculture University, Jobner, Jaipur-303 329, Rajasthan, India.

Corresponding Author: Anil Kumar, Department of Genetics and Plant Breeding, College of Agriculture, Bikaner Swami Keshwanand Rajasthan Agricultural University, Bikaner-334 006, Rajasthan, India. Email: anilkumarthakan@gmail.com

How to cite this article: Kumar, A., Sharma, N.K., Anita, Shekhawat, K. and Kumawat, S. (2025). Genetic and Phenotypic Insights into Seed Characteristics for Enhancing Yield Potential in Mungbean [*Vigna radiata* (L.) Wilczek]. *Indian Journal of Agricultural Research*. **59(10):** 1502-1509. doi: 10.18805/IJARe.A-6330.

Submitted: 27-10-2024 **Accepted:** 13-01-2025 **Online:** 22-02-2025

researchers investigated the variation on seed size for seed germination following seedling emergence and related agronomic aspects in mungbean. Generally, the larger seed has better field performance than the small seed. The 100-seed weight is one of the important characters and represents the size, quality and density of seeds which are also affected by environment and genetic factors (ICARDA, 2005). Therefore, it is essential to achieve basic scientific information about these seed characteristics.

High yield is the basic objective of all crop breeding programmes. In any program aimed at genetic improvement of yield, existence of variability is the basic requirement (Azam *et al*., 2018). The available genetic variability for the traits of interest, especially yield and its attributes are to be exploited by mungbean breeders in order to broaden and strengthen genetic potential. Yield is a complex character and depends upon the action and interaction of a number of factors. The relative contributions of these different characters to seed yield can be estimated by correlation analysis. However, correlation studies do not provide an exact picture of the relative importance of direct and indirect influence of each of them. The path coefficient analysis further allows the partitioning of correlation coefficients of yield-related characters into their direct and indirect effects (Gogoi *et al.,* 2024).

Keeping all these points in view, the present study was planned to assess genetic variability, heritability, genetic advance, correlation and path coefficient for seed yield and its contributing seed traits in mungbean in order to identify the most promising traits of interest and genotypes to be considered in future mungbean crop improvement programmes.

MATERIALS AND METHODS

The experimental material consisting of thirty-five genotypes were procured from NBPGR, Regional Station, Jodhpur; Rajasthan Agricultural Research Institute, Durgapura, Jaipur; Agricultural Research Station, Sriganganagar and Agricultural Research Station, Mandor, Jodhpur is given in Table 1. Field experiments were conducted at College of Agriculture, Bikaner, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan during summer-2019 and *Kharif*-2019. The experimental material consisted of 35 genotypes of mungbean was evaluated in randomized block design with three replications accommodating 3 meter long two rows per replication at 30 cm spacing under sprinkler irrigated situation in four different environments created by four different dates of sowing *viz.,* (i) summer season: (A) early sowing (6th March 2019) and (B) late sowing (20th March 2019); (ii) *Kharif* season: (C) early sowing (6th July 2019) and (D) late sowing (20th July 2019). All the recommended package of practices was adopted to raise a good crop. The observation for seed yield was recorded on individual plant basis on five randomly selected plants from each genotype of each replication.

The laboratory experiment was conducted from the harvested seeds with same 35 genotypes of mungbean for three replications of each mungbean genotype under completely randomized design (CRD) studied at room temperature at Department of Biotechnology, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan during *Kharif*-2020. The data on seven seed parameters *viz.*, 100-seed weight, seed volume, true density, bulk density, porosity, water absorption capacity and water absorption index studied at room temperature were estimated and recorded. The procedure adopted to record the observations for each character is given below:

100-seed weight (g)

Well dried 100-seeds were counted from bulk seeds of each genotype and weighed on electrical balance.

Seed volume (µl/seed)

Seed volume was measured by 'Liquid displacement technique' (Shepherd and Bhardwaj, 1986). Water was used to determine seed volume. For each mungbean genotype 100-seeds were weighed and put into a 100 ml measuring cylinder containing 15 ml (initial reading) of water that could completely cover all the seeds. Seed volume was calculated according to Mohsenin (1986) by using the formula:

$$\text{Seed volume (µl/seed)} = \frac{\text{Final reading - Initial reading}}{100}$$

True density (g/cm^3)

True density was determined using the 'Toluene displacement method' (Mohsenin, 1986; Singh and Goswami, 1996). Toluene (200 ml) was filled in a 500 ml graduated measuring cylinder and 100 g seeds were immersed in it. The amount of toluene displaced was recorded. The true density was estimated as the ratio of sample mass to the volume of displaced toluene.

Bulk density (g/cm^3)

Bulk density was determined following the method reported by Singh and Goswami (1996) and Gupta and Das (1997) by filling a 500 ml cylinder with seeds from a height of 15 cm at a constant rate. Excess seeds were levelled off with a metal rod and then the contents were weighed. Bulk densities were calculated as the ratio of the mass of the sample to the volume of the container and expressed in gcm^{-3}. Tests were carried out without tapping the cylinder and compacting the seeds.

$$\text{Bulk density (g/cm}^3\text{)} = \frac{M}{V}$$

Where,

M = Mass of seed in gram.

V = Volume of container in cm^3.

Porosity (%)

The porosity of bulk seed was computed from the values of true density and bulk density using the following formula (Singh and Goswami, 1996):

$$\text{Porosity (\%)} = \left\{1 - \frac{\text{B.D.}}{\text{T.D.}}\right\} \times 100$$

Where,
B.D. = Bulk density (in gcm^{-3}).
T.D. = True density (in gcm^{-3}).

Water absorption capacity (mg/seed)

To calculate the water absorption capacity, 100 seeds from each replication were weighted, soaked in water and was maintained at room temperature for 12 hours. The seeds were then removed from water and the excess moisture on the seed surface was removed with filter paper and seeds were weighted. Water absorption capacity in terms of mg per seed was calculated as per Mohsenin (1986):

$$WAC\ (mg/seed) = \frac{\text{Weight after soaking - Weight brfore Soaking}}{100}$$

Where,
WAC = Water absorption capacity.

Table 1: Details of mungbean genotypes used in investigation.

Name of genotype	Year of collection	Source of procurement
Germplasm procured from NBPGR, Regional Station, Jodhpur		
IC-39269	1993	Jodhpur, Rajasthan
IC-39300	1993	Jaswasar, Bikaner,Rajasthan
IC-39328	1993	Lalela, Barmer, Rajasthan
IC-39352	1993	Manduwa, Barmer, Rajasthan
IC-39399	1993	Jaspura, Palanpur, Gujarat
IC-39409	1993	Kapara, Banaskantha, Gujarat
IC-39454	1988	Surendranagar, Gujarat
IC-39492	1988	Dudhai, Mahesana, Gujarat
IC-39608	1992	Nevra, Jodhpur, Rajasthan
IC-39610	1992	Osian, Jodhpur, Rajasthan
IC-52076	1992	*
IC-52081	1992	*
IC-52082	1992	*
IC-52087	1992	*
IC-102792	1986	Banar, Jodhpur, Rajasthan
IC-102821	1986	Gidani, Jaipur, Rajasthan
IC-102857	1986	Khasur, Dholpur, Rajasthan
IC-103014	1986	Alampur, Kheda, Gujarat
IC-103059	1986	Krakas, Amreli, Gujarat
IC-103244	1986	Bhrwasa, Didwana, Nagaur, Raj.
IC-338868	1990	Sanari, Barmer, Rajasthan
Varieties/ genotypes procured from Agriculture University, Jodhpur		
Sweta		CSAVAT, Kanpur
IPM-02-3		ICAR-IIPR, Kanpur
IPM-02-14		ICAR-IIPR, Kanpur
Samrat (PDM-139)		ICAR-IIPR, Kanpur
GM-4		AAU, Pulse Res.Station,Vadodara
MH 2-15		CCSHAU, Hisar
MH-421		CCSHAU, Hisar
Varieties/ genotypes procured from RARI, Durgapura, Jaipur		
RMG-62		SKRAU-ARS, Durgapura, Jaipur
RMG-344		SKRAU-ARS, Durgapura, Jaipur
Keshwanand Mung-1 (RMG-975)		SKNAU-RARI, Durgapura, Jaipur
Varieties/ genotypes procured from ARS, Sriganganagar		
SML-668		PAU, Ludhiana
SML-832		PAU, Ludhiana
Ganga-1		SKRAU-ARS, Sriganganagar
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 various traits.

Character	Sources of variation		
	Replications	Genotypes	Error
d. f.	2	34	68
100-seed weight (g)	0.00104	0.42034**	0.00081
Seed volume (µl/seed)	0.37143	70.32885**	0.24398
Bulk density (g/cm³)	0.00013	0.00240**	0.00016
True density (g/cm³)	0.00083	0.01712**	0.00031
Porosity (%)	0.88748	76.38915**	0.98074
Water absorption capacity (mg/seed)	0.09002	219.68103**	0.64371
Water absorption index	0.00002	0.11217**	0.00042
Seed yield per plant (g)	0.52600	24.6960**	0.22710

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

Table 3: Mean performance of mungbean genotypes for seed yield per plant over four environments.

Name of genotype	Seed yield per plant (g)				
	Env. -A	Env. -B	Env. -C	Env. -D	Pooled
IC-39269	5.47	7.70	14.94	13.65	10.44
IC-39300	4.00	6.67	11.17	9.60	7.86
IC-39328	5.47	8.28	13.96	9.73	9.36
IC-39352	6.20	5.87	13.30	8.53	8.47
IC-39399	5.80	7.60	9.91	10.77	8.52
IC-39409	5.67	7.63	10.11	9.87	8.32
IC-39454	5.73	6.13	10.91	10.67	8.36
IC-39492	9.93	6.13	13.27	16.10	11.36
IC-39608	7.73	5.73	7.16	11.00	7.91
IC-39610	8.07	5.73	8.21	10.00	8.00
IC-52076	5.40	8.67	7.52	8.00	7.40
IC-52081	6.07	9.36	8.69	8.00	8.03
IC-52082	7.00	8.80	7.73	11.00	8.63
IC-52087	8.67	8.53	8.06	10.13	8.85
IC-102792	7.47	6.67	9.83	10.00	8.49
IC-102821	4.67	10.26	11.17	15.00	10.28
IC-102857	7.27	9.86	9.33	14.00	10.11
IC-103014	6.87	10.33	9.85	10.00	9.26
IC-103059	9.33	8.40	9.97	10.00	9.43
IC-103244	6.40	6.27	8.37	6.93	6.99
IC-338868	11.67	6.27	8.43	10.00	9.09
Sweta	6.20	8.80	7.06	11.00	8.26
IPM-02-3	4.60	9.59	12.37	11.00	9.39
IPM-02-14	4.53	10.46	12.54	8.00	8.88
Samrat (PDM-139)	4.87	9.66	15.21	9.07	9.70
GM-4	5.47	13.89	19.22	14.00	**13.15**
MH 2-15	5.60	9.41	12.87	11.00	9.72
MH-421	4.67	11.42	10.98	8.93	9.00
RMG-62	6.53	14.59	12.72	11.73	11.39
RMG-344	6.40	11.13	15.76	15.00	12.07
Keshwanand Mung-1	6.93	6.67	17.44	11.73	10.69
SML-668	5.07	9.32	10.87	9.33	8.65
SML-832	5.87	14.61	14.44	9.60	11.13
Ganga-1	6.73	5.47	15.11	9.20	9.13
MUM-2	5.13	9.39	13.23	14.00	10.44
Overall mean	6.38	8.72	11.48	10.76	9.34
Range	4.00-11.67	5.47-14.61	7.06-19.22	6.93-16.10	6.99-13.15

Water absorption index

The water absorption index was obtained by dividing the water absorption capacity of a single seed by its size/weight (Williamsa *et al*., 1983).

$$\text{Water absorption index} = \frac{\text{Water absorption capacity (mg/seed)}}{\text{Original seed size (g)}}$$

Analysis of variance (ANOVA) was done by subjecting the data to the statistical method described by Panse and Sukhatme (1985). The statistical analysis was performed using INDOSTAT 8.1 and XLSTAT 2021.2.2 software. Genotypic variances and phenotypic variances were calculated according to Johnson *et al.* (1955); Comstock and Robinson (1952), respectively from the expectations of mean squares by using an ANOVA table for each character. Heritability in a broad sense was calculated as suggested by Burton and Devane (1953). The expected genetic advance for each character was calculated as suggested by Johnson *et al.* (1955). Phenotypic correlation and path coefficients of variation were computed as per the method given by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among genotypes for all seven seed traits which indicate the presence of good amount of variability in the genotypes and scope of selection for genetic improvement of mungbean (Table 2). The results confirmed the findings of Adlan (2019) in mungbean, Get *et al.* (2019) in lentil, Pal *et al.* (2020) and Meena *et al.* (2021) in mothbean.

On the basis of mean performance over environments, highest seed yield was observed in GM 4 followed by RMG 344, RMG 62, IC 39492, SML 832, Keshwanand Mung 1, MUM 2, IC 39269, IC 102821, IC 102857, MH 2-15, Samrat, IC 103059 and IC 39328 (Table 3). Mungbean is a self-pollinated crop therefore; all above mentioned varieties/ genotypes could directly be used for cultivation under irrigated normal soil and water situation of arid zone as well as in future breeding programme to develop superior varieties. Similar findings were earlier reported by Baraki *et al.* (2020); Samyuktha *et al.* (2020) and Kumar *et al.* (2024).

High GCV and PCV were found for water absorption capacity, water absorption index, porosity and seed yield per plant. Include the lowest and highest values for all traits. Therefore, high degree of heritable genetic variability in these seed traits reveals the good scope of selection for these traits (Table 4). Similar findings were earlier reported by Adlan (2019) in mungbean and Get *et al.* (2019) in lentil. High heritability coupled with high/moderate genetic advance as per cent of mean was observed for water absorption capacity, water absorption index, porosity, seed volume, 100-seed weight, true density and seed yield per plant. These traits are governed by additive gene action

Table 4: Genetic variability parameters of mungbean genotypes for seed characteristics.

Name of character	Mean	Range	Coefficient of variation		Heritability % (broad sense)	Genetic advance at 5%	Genetic advance as per cent of mean at 5%
			Genotypic	Phenotypic			
100- seed weight (g)	4.17	3.53-5.34	8.97	8.98	99.80	0.77	18.46
Seed volume (µl/seed)	31	20-40	15.71	15.74	99.70	9.94	32.30
Bulk density (g/cm³)	1.04	0.98-1.08	2.62	2.71	93.20	0.05	5.20
True density (g/cm³)	1.35	1.14-1.55	5.54	5.59	98.20	0.15	11.31
Porosity (per cent)	22.54	8.28-33.25	22.24	22.39	98.70	10.26	45.53
Water absorption capacity (mg/seed)	24.15	7.75-41.64	35.38	35.43	99.70	17.58	72.78
Water absorption index	0.58	0.22-1.02	33.49	33.55	99.60	0.40	68.96
Seed yield per plant (g)	9.34	6.99-13.15	14.33	15.21	88.76	2.60	27.81

Table 5: Estimates of phenotypic and genotypic correlation coefficient of mungbean genotypes on seed yield for seed characteristics.

Name of character		100-seed weight	Seed volume	Bulk density	True density	Porosity	Water absorption capacity	Water absorption index	Seed yield per plant
100-seed weight	P	1.000	0.507**	-0.030	-0.130	-0.091	0.447**	0.185	0.324*
	G	1.000	0.508	-0.033	-0.131	-0.092	0.449	0.187	0.339
Seed volume	P		1.000	-0.087	-0.040	-0.002	0.302**	0.159	0.103
	G		1.000	-0.092	-0.039	-0.002	0.303	0.160	0.111
Bulk density	P			1.000	-0.102	-0.484**	-0.186	-0.204*	-0.076
	G			1.000	-0.104	-0.482	-0.191	-0.210	-0.082
True density	P				1.000	0.916**	0.139	0.191*	0.203*
	G				1.000	0.927	0.141	0.194	0.210
Porosity	P					1.000	0.207*	0.257**	0.203*
	G					1.000	0.208	0.258	0.213
Water absorption capacity	P						1.000	0.960**	0.628**
	G						1.000	0.960	0.658
Water absorption index	P							1.000	0.601**
	G							1.000	0.628
Seed yield per plant	P								1.000
	G								1.000

Table 6: Estimates of phenotypic and genotypic path coefficient of mungbean genotypes on seed yield for seed characteristics

Character		100-seed weight	Seed volume	Bulk density	True density	Porosity	Water absorption capacity	Water absorption index	Correlation with seed yield per plant
100-seed weight	P	0.7527	0.3818	-0.0227	-0.0977	-0.0688	0.3366	0.1396	0.324*
	G	0.8965	0.4557	-0.0292	-0.1178	-0.0822	0.4024	0.1675	0.339
Seed volume	P	-0.0562	-0.1107	0.0096	0.0045	0.0002	-0.0334	-0.0176	0.103
	G	-0.0372	-0.0731	0.0067	0.0028	0.0001	-0.0221	-0.0117	0.111
Bulk density	P	0.0180	0.0516	-0.5949	0.0608	0.2879	0.1104	0.1216	-0.076
	G	-0.0143	-0.0400	0.4370	-0.0454	-0.2106	-0.0835	-0.0919	-0.082
True density	P	-0.2090	-0.0648	-0.1647	1.6107	1.4753	0.2244	0.3081	0.203*
	G	0.0892	0.0264	0.0704	-0.6788	-0.6295	-0.0959	-0.1317	0.210
Porosity	P	0.1534	0.0034	0.8119	-1.5368	-1.6777	-0.3466	-0.4307	0.203*
	G	-0.0852	-0.0015	-0.4477	0.8615	0.9289	0.1932	0.2400	0.213
Water absorption capacity	P	-0.7041	-0.4753	0.2922	-0.2193	-0.3253	-1.5744	-1.5113	0.628**
	G	-0.9909	-0.6681	0.4218	-0.3118	-0.4591	-2.2077	-2.1192	0.658
Water absorption index	P	0.3692	0.3171	-0.4070	0.3809	0.5111	1.9112	1.9910	0.601**
	G	0.4811	0.4113	-0.5412	0.4996	0.6654	2.4715	2.5749	0.628

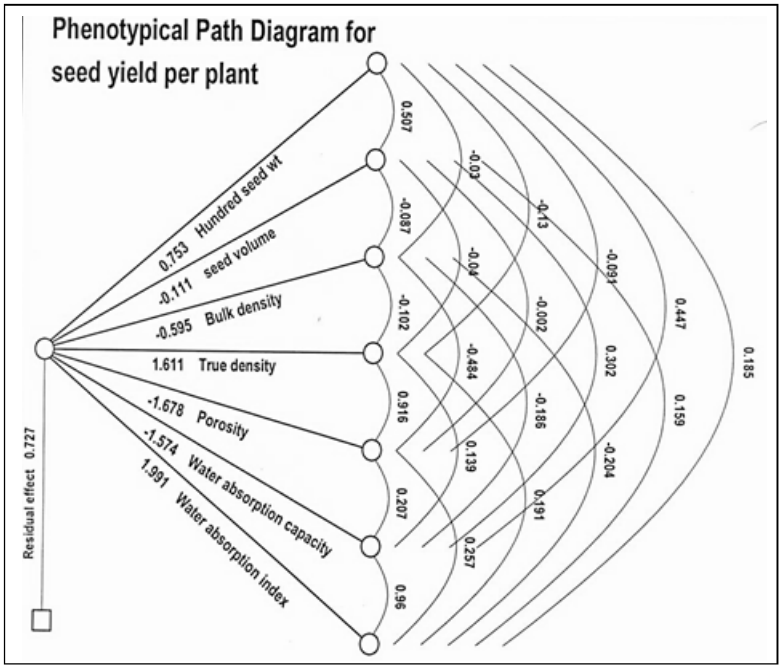


Fig 1: Phenotypic path diagram of seed traits for seed yield in mungbean.

and therefore, may be improved through direct selection. These results are accordance with the earlier finding of Adlan (2019) in mungbean, Get *et al.* (2019) in lentil, Pal *et al.* (2020) and Meena *et al.* (2021) in mothbean.

The traits namely; 100-seed weight, true density, porosity, water absorption capacity and water absorption index had significantly positive correlation with seed yield per plant (Table 5). Positive direct effect on seed yield per plant was observed for water absorption index and 100-seed weight at both phenotypic and genotypic levels; whereas, true density at phenotypic level and porosity and bulk density at genotypic level (Table 6). The residual effect was found high for seed traits at both phenotypic and genotypic levels which indicate that seed traits were also contributed to seed yield but major contribution came from other traits like agro-morphological and physio-biochemical traits (Fig 1). These findings are in accordance as reported by Adlan (2019) in mungbean, Pal *et al.* (2020) and Meena *et al.* (2021) in mothbean.

CONCLUSION

Highly significant differences were found among all genotypes for all seed traits studied. The high degree of genetic variability along with high heritability and high genetic advance as per cent of mean were observed for water absorption capacity, water absorption index and porosity which reveals that these characters were under the control of additive gene action and therefore, form the basis of selection for mungbean improvement programme. Among seed traits, water absorption index and 100-seed weight had positive correlation with seed yield and directly contributed towards seed yield which can help in the improvement of seed yield in mungbean.

ACKNOWLEDGEMENT

The present study was supported by Prof. (Dr.) N.K. Sharma, SKRAU, Bikaner; for the best guidance and support. I am also extremely grateful to Dr. Om Veer Singh, Principal Scientist and Officer-In-Charge, NBPGR, RS, Jodhpur; Prof. (Dr.) B.R. Chaudhary, Hon'ble Vice-Chancellor, Agriculture University, Jodhpur; Prof. (Dr.) O.P. Khedar, O/I, MULLaRP, RARI, Durgapura, Jaipur and Prof. (Dr.) Vijay Prakash, ARS, Sriganganagar for providing valuable research material for my Ph.D. research experimentation.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Adlan, P. (2019). Morpho-physiological Studies in Mungbean [*Vigna radiata* (L.) Wilczek]. Thesis, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Rajasthan). pp 123.

Anita, Kumhar, S.R., Kumar, A., Suchitra, Kulheri, A., Shekhawat, P.K. and Yadav, G.L. (2022). Correlation and path analysis for pod yield and its component traits in mungbean [*Vigna radiata* (L.) Wilzeck] genotypes. *Legume Research*. **48(1):** 26-31. doi: 10.18805/LR-4906.

Azam, M., Hossain, M., Alam, M., Rahman, K., Hossain, M. (2018). Genetic variability, heritability and correlation path analysis in mungbean [*Vigna radiata* (L.) Wilczek]. *Bangladesh Journal of Agricultural Research*. **43(3):** 407-416.

Baraki, F., Gebregergis, Z., Belay, Y., Berhe, M. and Zibelo, H. (2020). Genotype × environment interaction and yield stability analysis of mungbean [*Vigna radiata* (L.) Wilczek] genotypes in Northern Ethiopia. *Cogent Food and Agriculture*. **6(1):** 1729581-1729595.

Burton, G.W. and Devane, E.M. (1953). Estimation of heritability in tall fescus (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal.* **45:** 478-480.

Comstock, R.R. and Robinson, H.F. (1952). Genetic parameters, their estimation and significance. *Proceeding of Sixth International Grassland Congress*. **1:** 248-251.

Dewey, D.R. and Lu, H.K. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal*. **51(6):** 515-518.

Directorate of Pulses Development, (2022). Annual Report 2021-22. Retrieved from https://dpd.gov.in/Annual Report (2021-22).pdf.

Get, S., Gothwal, D.K., Choudhary, R.C. and Shekhawat, K. (2019). Genetic variability in lentil (*Lens culinaris* M.) genotypes for seed and seedling characteristics. *Journal of Pharmacognosy and Phytochemistry*. **8(3):** 3000-3004.

Gogoi, L.R., Behera, P.P., Borah, N. and Sarma, R.N. (2024). Genetic variability and correlation studies for yield and yield attributing traits in mungbean [*Vigna radiata* (L.) Wilczek]. *Legume Research*. doi: 10.18805/LR-5241.

Gupta, R.K. and Das, S.K. (1997). Physical properties of sunflower seeds. *Journal of Agricultural Engineering Research*. **66:** 1-8.

ICARDA, (2005). ICARDA Annual Report 2004. International Centre for Agricultural Research in the Dry Areas, Aleppo, Syria. 121pp.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. (1955). Estimate of genetic and environmental variability in soybean. *Agronomy Journal*. **47:** 314-318.

Kumar, A., Sharma, N.K., Anita, Shekhawat, K., Kumawat, S. (2024). Stability analysis for agro-morphological and physio-biochemical traits in mungbean [*Vigna radiata* (L.) Wilzeck] under arid environment. *Legume Research*. **47(5):** 723-730. doi: 10.18805/LR-5058.

Meena, S., Sharma, N.K., Sharma, A.K., Kumar, R., Gaur, G.K. (2021). Study of genetic variability parameters for seed yield and component traits in mothbean [*Vigna aconitifolia* (Jacq) Marechal] under arid environment. *Biological Forum*. **13(3a):** 180-183.

Mohsenin, N.N. (1986). Physical properties of plants and animal materials: Structure, physical characteristics and mechanical properties. Gordon and Breach Science Publishers, New York. pp. 881.

Pal, S., Sharma, N.K., Sharma, A.K., Kumar, A. and Meena, S. (2020). Study of genetic variability parameters for seed yield and component traits in moth bean [*Vigna aconitifolia* (jacq) Marechal]. *International Journal of Chemical Studies*. **8(4):** 2638-2641.

Panse, V.G. and Sukhatme, P.V. (1985). Statistical Methods for Agricultural Workers, ICAR, New Delhi. pp. 357.

Peleg, K. (1985). Produce Handling, Packaging and Distribution. The AVI Publishing Company Inc., Westport, Connecticut (USA). pp. 625.

Rahmianna, A.A., Basuki, T., Kote, M., Seran, Y.L. and Rachaputi, R.C. (2021). Increasing productivity of mungbean [*Vigna radiata* (L.) Wilczek] under subsistence farming in Eastern Indonesia. *In IOP Conference Series: Earth and Environmental Science*. **911(1):** 012029. doi: 10.1088/1755-1315/911/1/012029.

Samyuktha, S.M., Malarvizhi, D., Karthikeyan, A., Dhasarathan, M., Hemavathy, A.T., Vanniarajan, C., Sheela, V., Hepziba, S.J., Pandiyan, M. and Senthil, N. (2020). Delineation of genotype x environment interaction for identification of stable genotypes to grain yield in mungbean. *Frontiers in Agronomy.* **2:** 577911-577921.

Shepherd, H., Bhardwaj, R.K. (1986). Moisture dependent physical properties of pigeon pea. *Journal of Agricultural Engineering Research*. **35:** 227-234.

Singh, C., Singh, P. and Singh, R. (2015). Modern Techniques of Raising Field Crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi. pp. 386.

Singh, K.K. and Goswami, T.K. (1996). Some physical properties of cumin seed [*Cuminum cyminum* L.]. *Journal of Agricultural Engineering Research*. **64(1):** 93-98.

Sneha, M., Saravanan, S., Premkumari, S.M. and Pillai, M.A. (2020). An appraisal of genetic divergence in some indigenous collections of mungbean [*Vigna radiata* (L.) Wileczek]. *Electronic Journal of Plant Breeding.* **11(2):** 620-625.

Williamsa, P.C., Nakoul, H. and Singh, K.B. (1983). Relationship between cooking time and some physical characteristics in chickpeas (*Cicer arietinum* L.). *Journal of the Science of Food and Agriculture*. **34:** 492-496.