Biological Forum – An International Journal 14(3): 732-740(2022)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Genetic Variability and Inter-Relationships among Grain Physical Quality Traits in Mungbean (*Vigna radiata* L. Wilczek)

Jenifer Sylvia J.[1], Murugan E.[1], Muthuramu S.[1], Renuka R.[2] and Vellaikumar S.[2]*
[1]Department of Plant Breeding and Genetics,
Agricultural College and Research Institute, TNAU, Madurai (Tamil Nadu), India.
[2]Centre of Excellence for Innovations, Department of Biotechnology,
Agricultural College and Research Institute, TNAU, Madurai (Tamil Nadu), India.

(Corresponding author: Murugan E.)*
(Received 29 May 2022, Accepted 26 July, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Hundred seed weight is one of the crucial quantitative traits which directly influences the yield. Seeds are classified based on their hundred seed weight as bold (> 5 g), medium bold (4–4.9 g) and small seeds (< 4 g). Bold seeded types are preferred by most of the consumers for making sundal, sprouts, snacks, etc., Limited information is only available on the mungbean grain quality traits. Thus, the present study was undertaken to estimate the genetic variability and association for fourteen grain quality traits in 20 mungbean genotypes. The hundred seed weight is an important grain quality trait that is influenced by other physical quality traits like dry seed volume, soaked seed volume, hydration capacity, swelling capacity, hydration index and swelling index, etc., According to the correlation studies from the twenty green gram genotypes, a highly significant and positive association was observed for hundred seed weight with dry seed weight followed by soaked seed volume, soaked seed weight, cooking time, dry seed volume, dry seed density and swelling capacity. Path analysis revealed that water absorption percentage recorded the highest direct effect followed by hydration capacity, dry seed weight and dry seed density. The traits like soaked seed weight (g), water absorption percentage (%), volume expansion percentage (%), hydration capacity, hydration index, swelling capacity and swelling index expressed high PCV, GCV, heritability and genetic advance as a percentage of the mean. Hence, these traits can be given importance during selection for improving quality aspects in green gram as they exhibit more genetic variability and responds well to selection.

Keywords: Correlation, physical quality, sensory evaluation and mungbean.

INTRODUCTION

India has obtained a ubiquitous position as a prime producer, leading consumer and exporter of pulses among the other countries. Pulses are an indispensable source of protein alongside low fat and high fiber content in most of the developing countries. On top of that, they are also a great source of vitamins and minerals namely, folate, vitamin-'C', iron, zinc and magnesium. Mungbean (*Vigna radiata* L. Wilczek) is the third most important pulse crop in the world which occupies an extensive portion of the vegetarian diet as an alternative to meat in all over the world. It is the best and cheapest source of daily dietary nutrition for human and animal consumption. Globally, mungbean occupies an area of about 7.3 million ha with a productivity of 731 Kg/ha. Of the total global mungbean production of 5.3 million tonnes, India and Myanmar each contribute 30% to the production (Nair and Schreinemachers 2020). Mungbean encompasses protein, fiber and ash in the range of 22.9–26.3%, 3.80–7.00% and 3.1–4% respectively (Enyiukwu *et al*., 2020; Kumar and Pandey 2020). It also contains various biochemical compounds (Hou *et al.,* 2019) which have nephroprotective, hepato-protective, anti-inflammatory and anticancer properties (Gupta *et al.,* 2018; Sudhakaran and Bukkan 2021).

Having a prior and foremost knowledge of the physicochemical properties of mungbeanhelp in transportation, storage, processing, seed quality assessment and marketing (Sastry *et al*., 2019). Hundred seed weight is one of the important quality traits in mungbean as most of the varieties used for sundal, sprouts and snacks purposes are bold seeded (> 5 g). It is influenced by various physicochemical properties of seeds alike hydration capacity, swelling capacity, water absorption capacity and volume expansion ratio. Hydration and cooking are two both different and interrelated processes. Hydration should occur before or during cooking so that seed softening and starch gelatinization occurs which are the two vital parameters of cooked grain (Honnappa *et al.,* 2018). Cooking quality largely depends on hydration capacity and volume expansion ratio. It is also determined by starch, the internal structure of the seed, permeability and compactness of the seed coat.

In India, Mungbean breeding is mainly focused on yield improvement alongside the development of biotic and abiotic stress resistance and less consideration is given to quality aspects of mungbean. Limited information is only available on the physicochemical properties and cooking quality based on the breeding lines and mini core collections, etc., Henceforth, the present experimental study was undertaken to assess the genetic variability and association studies among the hundred seed weight and physiochemical traits in mungbean.

MATERIALS AND METHODS

Plant material. Twenty mungbean genotypes were raised in the research farm of the Department of Plant Breeding and Genetics, Agricultural College and Research Institute (AC&RI), Madurai in January 2022. A spacing of 30 × 10 cm was adopted. Recommended cultural and agronomic practices were undertaken at timely intervals. The harvested seeds were used for determining the physicochemical traits namely hundred seed weight (g), dry seed weight (g), soaked seed weight (g), dry seed volume (g/ml), soaked seed volume(g/ml), dry seed density, soaked seed density, hydration capacity, hydration index, water absorption percentage (%), volume expansion percentage (%), swelling capacity, swelling index and cooking time (min).

Physico-chemical properties. The methodology of Santhan and Shivshankar (1978) was used to determine the physical properties of seeds namely, hundred seed weight, dry seed weight, soaked seed weight, dry seed volume, soaked seed volume, dry seed density, soaked seed density, hydration capacity, hydration index, water absorption percentage, volume expansion percentage, swelling capacity and swelling index. Hundred seed weight was ascertained by weighing 100 seeds in triplicate of each genotype using an electronic weighing balance and their mean value was expressed in g. 50 seeds of each genotype are soaked in distilled water for overnight.

A. Dry seed weight (DSW). The initial weight of fifty seeds was taken as dry seed weight(g).

B. Soaked seed weight (SSW). The weight of overnight soaked fifty seeds was ascertained as soaked seed weight (g).

C. Dry seed volume (DSV). The volume of seeds was determined by the volume displacement method. 50 seeds were dispersed in 50 ml water contained in a 100 ml measuring cylinder and the immediate displacement in the volume of water was taken as dry seed volume.

D. Soaked seed volume (SSV). The volume of soaked seeds was measured by placing the soaked seeds in a 100 ml measuring cylinder containing 50 ml of water. The immediate displacement in the volume was taken as soaked seed volume.

$$DD = \frac{\text{Dry seed weight}}{\text{Dry seed volume}}$$

E. Dry seed density (DD). The density of seed was ascertained by dividing dry seed weight by dry seed volume.

F. Soaked seed density (SD). The density of soaked seed was measured by the ratio of soaked seed weight to soaked seed volume.

$$SD = \frac{\text{Soaked seed weight}}{\text{Soaked seed volume}}$$

G. Water absorption percentage (WAP). The water absorption percentage was calculated by using the following formula,

$$WAP = \frac{SSW - DSW}{DSW} \times 100$$

H. Volume expansion percentage (VEP). The volume expansion percentage was ascertained by using the following formula,

$$VEP = \frac{SSV - DSV}{DSV} \times 100$$

I. Hydration capacity (HC). It is the weight gained by the seeds after being soaked in distilled water. It is calculated by the following formula,

$$HC = \frac{SSW - DSW}{\text{No. of seeds}}$$

J. Hydration index (HI). The hydration index is the ratio of hydration capacity to the weight of one seed.

$$HI = \frac{HC}{\text{Weight of one seed}}$$

K. Swelling capacity (SC). It is measured as the difference between the volume displaced by seeds before and after soaking in water.

$$SC = \frac{SSV - DSV}{\text{No. of seeds}}$$

L. Swelling index (SI). It is the ratio of swelling capacity to the volume of one seed.

$$SI = \frac{SC}{\text{Volume of one seed}}$$

M. Cooking time (CT). 25 seeds were dispersed in 100 ml distilled water and boiled at 100°c. The seeds were cooked until they were soft when pressed between fingers for softness. The time required to cook each genotype was noted and expressed in minutes.

Sensory evaluation. The cooked mungbean seeds were subjected to sensory evaluation for the identification of superior genotypes for cooking quality. The twenty cooked mungbean genotypes were evaluated by a panel of seven untrained judges for sensory attributes like texture (softness), taste (palatability) and overall acceptability. The following nine-point hedonic scale was used to score the sensory attributes.

9 - Like extremely
8 - Like very much
7 - Like moderately
6 - Like slightly

5 - Neither dislike nor like
4 - Dislike slightly
3 - Dislike moderately
2 - Dislike very much
1 - Dislike extremely

Statistical analysis. The data for fourteen traits of twenty genotypes were analyzed for genetic variability like GCV(%), PCV(%), heritability (%) and genetic advance as per mean (%). Path coefficient analysis was performed using OPSTAT software (Sheoran *et al.,* 1998) and the correlation matrix and correlogram was obtained using R- software (R Core Team, 2020).

Formulae

a. PCV & GCV - The estimation of PCV and GCV are based on the methods of Burton (1952)

$$PCV = \frac{\sqrt{\sigma_p^2}}{Mean} \times 100$$

$$GCV = \frac{\sqrt{\sigma_g^2}}{Mean} \times 100$$

Low	:	< 10 %
Moderate	:	10 – 20%
High	:	>20%

The classification of PCV and GCV was based on the suggestion of Sivasubramanian and Madhavamenon, 1973.

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

b. Heritability – It plays a significant role in the process of selection in breeding as it is based on additive genetic variance. Broad sense heritability is calculated as the ratio of genotypic variance to phenotypic variance (Lush, 1940).

As suggested by Johnson *et al.* (1955), heritability values are classified as follows,

Low	:	< 30 %
Moderate	:	30 – 60%
High	:	> 60%

$$GAM\ (\%) = \frac{GA}{\sigma_p^2} \times 100$$

c. Genetic advance as a percentage of mean – genetic advance is the genetic gain due to selection. It is usually expressed as a percentage of the mean.

The genetic advance as a percentage of mean values are classified according to Johnson *et al.* (1955)

Low	:	< 10 %
Moderate	:	10 – 20%
High	:	>20%

d. Genotypic correlation (r_g) – the equation of genotypic correlation is as follows,

$$r_g = \frac{\sigma_g\ (x.y)}{\sqrt{\sigma_{gx}^2 \cdot \sigma_{gy}^2}}$$

e. Path coefficient - The path coefficient analysis is done as suggested by Dewey and Lu (1959). It is used to assess the relative direct and indirect influence of the independent variable on the dependent variable.

The scale for categorizing direct and indirect effects was given by Lenka and Mishra (1973).

Negligible	:	0.00 – 0.09
Low	:	0.10 – 0.19
Moderate	:	0.20 – 0.29
High	:	0.30 – 1.00
Very high	:	> 1.00

RESULTS AND DISCUSSION

The mean performances of twenty genotypes for each grain physical quality were enlisted in Table 1. The mean performance helps in the identification of superior genotypes for grain quality traits. The mean values of hundred seed weight ranged from 3 g (RM 20-16) to 5.4 g (VGG 18002) with an average of 4.37g. The weight of dry and soaked seeds varied from 1.61 (Co 8) to 3 g (VGG 18002) and 2 (RM 20-13) to 4.67 g (VGG 18002) with an average value of 2.36 g and 3.10 g respectively. The mean values of the traits, dry seed volume and soaked seed volume extends from 2.44 g/ml to 4.67g/ml and 3.56 g/ml to 7.78 g/ml respectively. The highest mean value for traits such as dry seed and soaked seed volume was noticed in the genotype VGG 18002. For dry seed density and soaked seed density, the mean value extended from 0.36 (CO 8) to 0.83 (DGG- V2) and 0.43 (RM 20-13) to 0.72 (Co 8) respectively. The traits like water absorption percentage, hydration capacity and hydration index were found to have the highest mean value in Co 8 while it recorded the lowest mean values for swelling capacity (0.01 ml/seed) and swelling index (0.08).Relatively identical outcomes were published by Ghosh and Panda (2006a) and Ghosh and Panda (2006b) in both black gram and greengram. The genotype VGG 16046 registered the lowest mean values of 5.88 %**,** 0.001 g/seed and0.06 for traits such as water absorption percentage, hydration capacity and hydration index, respectively. RM 20-13 showed the highest mean values for volume expansion percentage (90.91 %) and swelling index (0.91). The cooking time for twenty genotypes varied from 17 min to 25 min. The genotype, Asha mung had the least cooking time of 17 min as compared to the other genotypes. Based on the mean value (Table 1), it was clear that the bold seeded genotypes recorded the highest value for seed weight and volume both before and after cooking. Whereas for other traits excluding cooking time and hundred seed weight, the medium bold seeded genotypes exhibited high mean values. The superior genotypes identified for different grain quality trait based on their performances for each trait are enlisted in Table 5.

Table 1: Mean performance of 14 Physical qualitative traits of 20 mungbean genotypes.

Genotypes	DSW	SSW	DSV	SSV	DD	SD	WAP	VEP	HC	HI	SC	SI	CT	HSW
VGG 16046	2.83	3.00	3.67	5.00	0.77	0.60	5.88	36.27	0.00	0.06	0.03	0.36	21.00	5.10
COGG 980	2.94	3.33	3.56	5.67	0.83	0.59	13.09	59.38	0.01	0.13	0.04	0.59	23.00	5.30
DGG V2	2.89	3.44	4.44	6.67	0.65	0.52	19.08	50.00	0.01	0.19	0.04	0.50	23.00	5.20
VGG 18006	2.79	3.56	4.00	6.33	0.70	0.56	27.65	58.33	0.02	0.28	0.05	0.58	20.00	5.00
VGG 18002	3.00	4.67	4.67	7.78	0.64	0.60	55.67	66.67	0.03	0.56	0.06	0.67	24.00	5.40
COGG 979	2.56	3.22	3.67	5.78	0.70	0.56	26.00	57.58	0.01	0.26	0.04	0.58	24.00	4.80
COGG 18-17	2.81	3.78	4.11	6.11	0.72	0.62	28.38	48.65	0.02	0.28	0.04	0.49	20.00	5.30
IPM 302-2	2.56	2.78	3.33	4.67	0.77	0.60	8.78	40.00	0.00	0.09	0.03	0.40	23.00	4.70
KM 20-192	2.44	3.11	3.56	5.56	0.69	0.56	27.23	56.25	0.01	0.27	0.04	0.56	21.00	4.40
KM 20-199	1.91	2.33	2.89	4.11	0.66	0.57	21.92	42.31	0.01	0.22	0.02	0.42	20.00	3.90
RM 20-13	1.78	2.00	2.44	4.67	0.73	0.43	12.50	90.91	0.00	0.13	0.04	0.91	19.00	3.30
RM 20-8	1.81	2.33	2.44	4.00	0.74	0.58	28.65	63.64	0.01	0.29	0.03	0.64	21.00	3.50
COGG 13-39	2.48	3.45	3.44	5.89	0.72	0.59	39.24	70.97	0.02	0.39	0.07	0.71	22.00	4.50
Asha mung	1.93	2.22	2.67	3.56	0.73	0.62	14.83	33.33	0.01	0.15	0.02	0.33	17.00	3.70
COGG 17-03	1.94	2.89	2.89	5.11	0.67	0.57	48.63	76.92	0.02	0.49	0.04	0.77	22.00	4.00
COGG 17-13	2.59	3.11	3.56	5.67	0.73	0.55	20.13	59.38	0.01	0.20	0.04	0.59	21.00	4.70
UPM 981	2.56	3.78	3.83	6.67	0.67	0.57	47.91	73.91	0.02	0.48	0.06	0.74	25.00	4.60
CO 7	2.11	3.00	3.11	4.56	0.68	0.66	42.11	46.43	0.02	0.42	0.03	0.46	19.00	3.80
CO 8	1.61	3.45	4.44	4.78	0.36	0.72	114.14	7.50	0.04	1.14	0.01	0.08	20.00	3.20
RM 20-16	1.67	2.56	3.22	4.44	0.52	0.58	53.60	37.93	0.02	0.54	0.05	0.38	18.00	3.00
MEAN	2.36	3.10	3.50	5.35	0.68	0.58	32.77	53.82	0.02	0.33	0.04	0.54	21.15	4.37
SE	0.05	0.07	0.08	0.12	0.02	0.01	0.91	1.12	0.00	0.01	0.01	0.01	0.48	0.08

DSW- Dry Seed Weight (g), SSW- Soaked Seed Weight (g), DSV- Dry Seed Volume (g/ml), SSV- Soaked Seed Volume (g/ml), DD- Dry seed Density, SD- Soaked seed Density, WAP- Water Absorption Percentage (%), VEP- Volume Expansion Percentage (%), HC- Hydration Capacity, HI- Hydration Index, SC – Swelling Capacity, SI- Swelling Index, CT- Cooking Time (min) and HSW- Hundred Seed Weight (g).

Variability studies. Johnson *et al.* (1955) put forward that GCV along with heritability would give a clear-cut idea about the extent of advance to be expected from the selection. The magnitude of GCV was slightly lesser than the PCV for all the fourteen traits signifying that the influence of the environment on these traits was less or negligible (Table 2). It was clearly depicted in the Fig. 1. Comparable findings were reported by Singh (2016) and Srivastava *et al.* (2020) in chickpea and Neyaz and Bajpai (2002) in pigeon pea.The highest GCV and PCV were exhibited by the traits like water absorption percentage (74.10% and 74.18%) followed by hydration index (74.11% and 74.16%) while the highest heritability and genetic advance as a percentage of mean were observed in hydration index (99.85% and 92.55%) followed by hydration capacity. High heritability alongside high genetic advance as a percentage of mean was reported by all the traits except for soaked seed density and cooking time, implying that these traits are controlled by additive gene action and selection would be effective (Fig. 2). The traits *viz*., soaked seed weight, water absorption percentage, volume expansion percentage, hydration capacity, hydration index, swelling capacity and swelling index expressed high PCV, GCV, heritability and genetic advance as a percentage of the mean. Hence, priority may be given during selection for improving respective traits as they exhibit more genetic variability.

Table 2: Variability, Heritability and Genetic advance for 14 qualitative traits.

Traits	PCV %	GCV %	Heritability (h^2) %	GA	GAM (%)
DSW	19.84	19.71	98.61	0.95	40.31
SSW	20.60	20.41	98.17	1.29	41.66
DSV	18.53	18.34	97.94	1.31	37.40
SSV	19.82	19.64	98.20	2.14	40.09
DD	14.51	14.23	96.11	0.20	28.74
SD	10.02	9.58	91.46	0.11	18.88
WAP	74.18	74.10	99.79	49.97	92.49
VEP	34.47	34.38	99.45	38.01	70.63
HC	61.81	61.76	99.82	0.02	87.11
HI	74.16	74.11	99.85	0.50	92.55
SC	38.96	36.16	86.14	0.03	69.14
SI	34.50	34.36	99.19	0.38	70.50
CT	10.23	9.84	92.59	4.13	19.51
HSW	17.65	17.49	98.20	1.56	35.70

DSW- Dry Seed Weight (g), SSW- Soaked Seed Weight (g), DSV- Dry Seed Volume (g/ml), SSV- Soaked Seed Volume (g/ml), DD- Dry seed Density, SD- Soaked seed Density, WAP- Water Absorption Percentage (%), VEP- Volume Expansion Percentage (%), HC- Hydration Capacity, HI- Hydration Index, SC – Swelling Capacity, SI- Swelling Index, CT- Cooking Time (min) and HSW- Hundred Seed Weight (g).

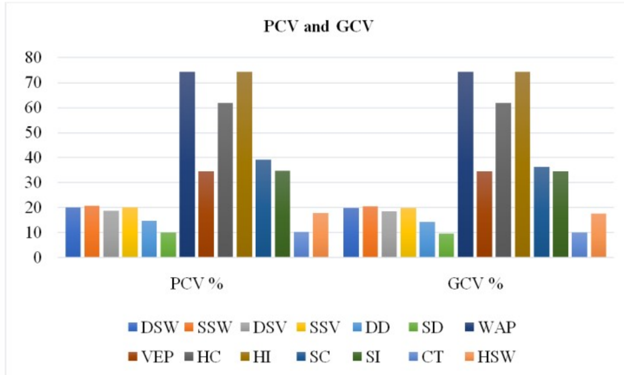

Fig. 1. PCV (%) and GCV (%) for 14 grain quality traits.

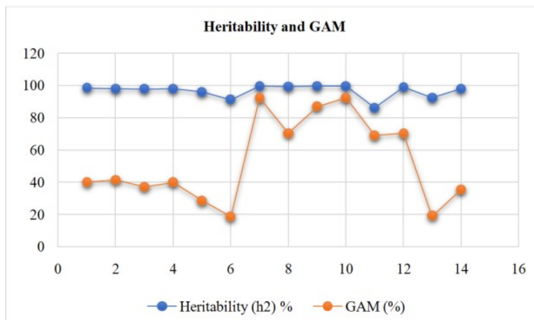

Fig. 2. Heritability (%) and Genetic Advance as a percentage of Mean (%) for 14 grain quality traits.

Correlation studies. Karl Pearson's correlation coefficient was constructed for 14-grain quality traits to quantify the association between hundred seed weight and other physicochemical traits. The correlation matrix for grain quality traits is depicted in Table 3. Highly positive significant association was observed for hundred seed weight with dry seed weight (0.98) followed by soaked seed volume (0.75), soaked seed weight (0.69), cooking time (0.63), dry seed volume (0.62), dry seed density (0.50) and swelling capacity (0.40) as shown in Fig. 3.

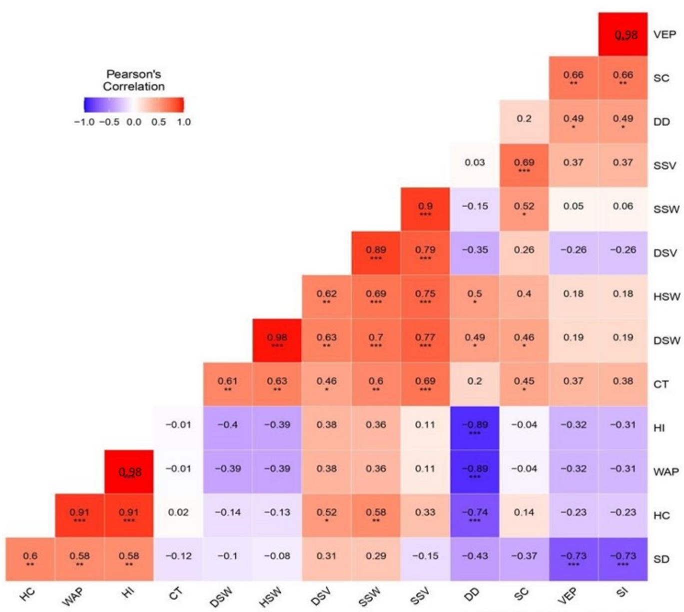

Fig. 3. Correlogram for 14 grain quality traits.

This was in accordance with the findings of Veni *et al.* (2015) in black gram except for soaked seed density. While the positive non-significant association was recorded for hundred seed weight with volume expansion percentage (0.18) and swelling index (0.18). A negative significant hydration index with hundred seed weight was reported by Veni *et al.* (2015) in black gram.

Dry seed volume and soaked seed volume were positively and significantly correlated with dry seed weight and soaked seed weight. Soaked seed density was positively correlated with soaked seed weight and dry seed volume while it showed a negative significant association with dry seed density. A positive and significant association was observed for water absorption percentage with soaked seed weight, dry seed volume and soaked seed density. Volume expansion percentage had a positive significant correlation with soaked seed volume and dry seed density. Hydration capacity and hydration index were intercorrelated with dry seed volume, soaked seed weight, soaked seed density and water absorption percentage which was in line with the results of Neyaz and Bajpai (2002) in pigeon pea, Ghosh and Panda (2006b) in green gram, Sethi *et al*. (2008) in pigeon pea, Singh (2016) in chickpea, Veni *et al.* (2015) in black gram and Honnappa *et al.* (2018) in chickpea. Hydration capacity and hydration index recorded a negative significant association with dry seed density. Swelling capacity and swelling index had a positive significant intercorrelation with soaked seed volume and volume expansion percentage. Veni *et al.* (2015) documented that the swelling capacity was positively inter-correlated with dry seed density but negatively inter-correlated with soaked seed density which was in alignment with the current outcome. Cooking time showed a highly positive association with dry seed weight, soaked seed weight, dry seed volume, soaked seed volume, volume expansion percentage, swelling capacity and index. Hence, the findings revealed that the bold seeded genotypes require more time for cooking compared to medium (COGG 18-17) and small-seeded genotypes (Asha mung), which was in alignment with the reports of Afzal *et al.* (2003). Cooking time was negatively correlated with soaked seed density, water absorption percentage and hydration index, implying that the cooking time will be considerably reduced by presoaking of seeds before cooking.

Path coefficient studies. The path coefficient splits the correlation coefficient into direct and indirect effects to measure both the direct and indirect contribution of each independent variable (cause) to the dependent variable (effect). It was based on the method followed by Dewey and Lu (1959) and given in Table 4. The residual effect was 0.022 which implies that the chosen traits are sufficient for the study.

Direct effect. The trait, water absorption percentage (1.92) recorded the highest direct effect followed by hydration capacity (1.61), dry seed weight (1.57) and dry seed density (1.05). A high direct positive effect was observed in volume expansion percentage (0.47) while a negligible direct effect was observed for dry seed volume (0.09) and cooking time (0.001). Hydration index expressed the highest negative direct effect (-1.72) followed by swelling index (-1.14) and soaked seed volume (-1.01) and a low direct negative effect was observed in soaked seed volume (-0.19) and swelling capacity (-0.14). A comparable result was obtained by Ghosh and Panda (2006a) for soaked seed weight, dry seed volume, soaked seed volume, hydration capacity and hydration index in urdbean. A negative direct effect on swelling capacity was also observed by Honnappa *et al.* (2018) in chickpea. The result obtained by Ghosh and Panda (2006b) in green gram was contrary for traits like dry seed volume, dry seed density, hydration capacity, swelling capacity and hydration index. Similar findings were reported by Veni *et al.* (2015) in black gram for swelling capacity, soaked seed weight, dry seed density and soaked seed density.

Indirect effect. The positive and very high indirect effect was expressed for soaked seed weight (1.104) and soaked seed volume (1.22) while the high positive indirect effect was exhibited by dry seed volume (0.99), dry seed density (0.79), swelling capacity (0.74) and cooking time (0.97) through dry seed weight on hundred seed weight. Dry seed weight (0.52) and swelling index (0.52) had a high indirect effect through dry seed density. Dry seed density (0.32), volume expansion percentage (0.55), swelling capacity (0.38) and swelling index (0.55) had a high indirect effect through soaked seed density on hundred seed weight. A very high indirect effect on hundred seed weight was observed for soaked seed density (1.15), hydration capacity (1.80) and hydration index (1.97) through water absorption percentage. Through hydration capacity, traits such as water absorption percentage (1.47), hydration index (1.47) and soaked seed weight (1.08) exhibited a very high indirect effect on hundred seed weight, while, dry seed volume (0.94), soaked seed volume (0.738, swelling capacity (0.34) and cooking time (0.36) recorded high indirect effect. But these results were contrary to Ghosh and Panda (2006b). Dry seed density (1.54), dry seed weight (0.677) and volume expansion percentage (0.55) had a high indirect effect on the hundred seed weight through hydration index.

Sensory evaluation. The sensory evaluation of the 20 cooked mungbean genotypes was done by a panel of seven members and the results are depicted in Table 6. The sensory evaluation along with the cooking time helps in the effective selection of superior genotype for cooking quality.

Taste, texture and overall acceptability were the sensory attributes assessed for the 20 genotypes using the 9-point hedonic scale ranging from 1 to 9. For texture, the genotypes, DGG V2, VGG 18002 and COGG 979 recorded the highest score (9) and the least score (6) was obtained by genotypes *viz.,* RM 20-13, COGG 17-03 and CO 7. The genotypes namely, COGG 980 and VGG 18006 recorded the highest score (9) followed by VGG 16046, DGG V2, VGG 18002, COGG 18-17, KM 20-199, COGG 13-39, COGG 17-13 and CO 7 obtained a score of 8 for taste. Based on the overall acceptability, the genotypes such as COGG 980, DGG V2, VGG 18006 and VGG 18002 were identified as superior genotypes for cooking quality. Thus, based on the observations, the bold seeded types were found to be superior to medium and small seeded types for cooking quality especially for palatability.

Table 3: Correlation among Physical properties and cooking time in mungbean.

Traits	DSW	SSW	DSV	SSV	DD	SD	WAP	VEP	HC	HI	SC	SI	CT	HSW
DSW	1													
SSW	0.70**	1												
DSV	0.63**	0.89**	1											
SSV	0.77**	0.90**	0.79**	1										
DD	0.49**	-0.15	-0.35**	0.03	1									
SD	-0.10	0.29*	0.31*	-0.15	-0.43**	1								
WAP	-0.39**	0.36**	0.38**	0.11	-0.89**	0.58**	1							
VEP	0.19	0.05	-0.26*	0.37**	0.49**	-0.73**	-0.32*	1						
HC	-0.14	0.58**	0.52**	0.33**	-0.74**	0.60**	0.91**	-0.24	1					
HI	-0.40**	0.36**	0.38**	0.11	-0.89**	0.58**	0.98**	-0.32*	0.91**	1				
SC	0.46**	0.52**	0.26	0.69**	0.20	-0.37**	-0.04	0.66**	0.14	-0.04	1			
SI	0.19	0.06	-0.26*	0.37**	0.49**	-0.73**	-0.31*	0.98**	-0.23	-0.31*	0.66**	1		
CT	0.61**	0.60**	0.46**	0.69**	0.20	-0.12	-0.01	0.37**	0.02	-0.02	0.45**	0.38**	1	
HSW	0.98**	0.69**	0.62**	0.75**	0.50**	-0.08	-0.39**	0.18	-0.13	-0.39**	0.40**	0.18	0.63**	1

* - significant at 5%, ** - significant at 1%

DSW- Dry Seed Weight (g), SSW- Soaked Seed Weight (g), DSV- Dry Seed Volume (g/ml), SSV- Soaked Seed Volume (g/ml), DD- Dry seed Density, SD- Soaked seed Density, WAP- Water Absorption Percentage (%), VEP- Volume Expansion Percentage (%), HC- Hydration Capacity, HI- Hydration Index, SC – Swelling Capacity, SI- Swelling Index, CT- Cooking Time (min) and HSW- Hundred Seed Weight (g).

Table 4: Path analysis for Physical properties and cooking time in mungbean.

Traits	DSW	SSW	DSV	SSV	DD	SD	WAP	VEP	HC	HI	SC	SI	CT	HSW
DSW	**1.5746**	-0.7061	0.0597	-0.1504	0.5266	0.0819	-0.7747	0.0888	-0.1088	0.6777	-0.0641	-0.2172	0.0010	0.989**
SSW	1.1042	**-1.0069**	0.0846	-0.1755	-0.1595	-0.2219	0.7151	0.0247	1.0815	-0.6253	-0.0671	-0.0618	0.0010	0.693**
DSV	0.9935	-0.8995	**0.0947**	-0.1540	-0.3754	-0.2302	0.7624	-0.1227	0.9476	-0.6669	-0.0314	0.2988	0.0008	0.618**
SSV	1.2231	-0.9127	0.0753	**-0.1936**	0.0285	0.1194	0.2147	0.1744	0.7386	-0.1885	-0.1001	-0.4246	0.0011	0.755**
DD	0.7931	0.1537	-0.0340	-0.0053	**1.0455**	0.3237	-1.7630	0.2342	-1.1828	1.5406	-0.0329	-0.5702	0.0004	0.503**
SD	-0.1720	-0.2979	0.0291	0.0308	-0.4511	**-0.7502**	1.1551	-0.3483	0.8174	-1.0110	0.0698	0.8457	-0.0002	-0.083
WAP	-0.6184	-0.3650	0.0366	-0.0211	-0.9343	-0.4393	**1.9727**	-0.1512	1.4758	-1.7251	0.0136	0.3686	0.0000	-0.387**
VEP	0.2987	-0.0531	-0.0248	-0.0721	0.5229	0.5580	-0.6369	**0.4683**	-0.1874	0.5567	-0.1054	-1.1437	0.0006	0.182
HC	-0.1060	-0.6741	0.0555	-0.0885	-0.7654	-0.3796	1.8020	-0.0543	**1.6156**	-1.5748	-0.0287	0.1325	0.0004	-0.065
HI	-0.6190	-0.3652	0.0366	-0.0212	-0.9342	-0.4399	1.9738	-0.1512	1.4757	**-1.7240**	0.0136	0.3689	0.0000	-0.386**
SC	0.7405	-0.4959	0.0218	-0.1423	0.2528	0.3842	-0.1971	0.3624	0.3408	0.1715	**-0.1362**	-0.8841	0.0008	0.419**
SI	0.2996	-0.0545	-0.0248	-0.0720	0.5222	0.5558	-0.6370	0.4692	-0.1876	0.5571	-0.1055	**-1.1416**	0.0006	0.182
CT	0.9710	-0.6156	0.0448	-0.1348	0.2280	0.1128	-0.0280	0.1758	0.3632	0.0237	-0.0681	-0.4295	**0.0016**	0.645**

Residual effect - 0.022

DSW- Dry Seed Weight (g), SSW- Soaked Seed Weight (g), DSV- Dry Seed Volume (g/ml), SSV- Soaked Seed Volume (g/ml), DD- Dry seed Density, SD- Soaked seed Density, WAP- Water Absorption Percentage (%), VEP- Volume Expansion Percentage (%), HC- Hydration Capacity, HI- Hydration Index, SC – Swelling Capacity, SI- Swelling Index, CT- Cooking Time (min) and HSW- Hundred Seed Weight (g).

Table 5: Superior genotypes identified for various grain quality traits based on their mean performances.

Traits	DSW	SSW	DSV	SSV	DD	SD	WAP	VEP	HC	HI	SC	SI	CT	HSW
Superior genotypes	VGG 18002	VGG 18002	VGG 18002	VGG 18002	COGG 980	CO 8	CO 8	RM 20-13	CO 8	CO 8	COGG 13-39	RM 20-13	Asha mung	VGG 18002

DSW- Dry Seed Weight (g), SSW- Soaked Seed Weight (g), DSV- Dry Seed Volume (g/ml), SSV- Soaked Seed Volume (g/ml), DD- Dry seed Density, SD- Soaked seed Density, WAP- Water Absorption Percentage (%), VEP- Volume Expansion Percentage (%), HC- Hydration Capacity, HI- Hydration Index, SC – Swelling Capacity, SI- Swelling Index, CT- Cooking Time (min) and HSW- Hundred Seed Weight (g).

Table 6: Sensory evaluation of twenty mungbean genotypes.

Genotypes	Texture (softness)	Taste (palatability)	Overall acceptability
VGG 16046	8	8	8
COGG 980	8	9	9
DGG V2	9	8	9
VGG 18006	8	9	9
VGG 18002	9	8	9
COGG 979	9	7	8
COGG 18-17	8	8	8
IPM 302-2	7	7	7
KM 20-192	8	7	8
KM 20-199	7	8	8
RM 20-13	6	7	7
RM 20-8	7	6	7
COGG 13-39	8	8	8
Asha mung	7	7	7
COGG 17-03	6	7	7
COGG 17-13	7	8	8
UPM 981	8	7	8
CO 7	6	8	7
CO 8	7	7	7
RM 20-16	7	6	7

CONCLUSION

Superior genotypes were identified based on the performance of each trait and presented in Table 5. The genotype, VGG 18002 was identified as the superior genotype for hundred seed weight, dry seed weight, soaked seed weight, dry seed volume and soaked seed volume. Co 8 is a desirable variety for soaked seed density, water absorption percentage, hydration capacity and hydration index. The genotype, RM 20-13 expressed high mean values for volume expansion percentage and swelling index. The genotype, COGG 13-39 recorded the high swelling capacity and the genotype, Asha mung recorded the lowest cooking time. Hence, these genotypes can be utilized in the hybridization programme for grain quality improvement. The bold seeded genotypes generally require more cooking time compared to medium and small-seeded genotypes. Dry seed weight, soaked seed volume, soaked seed weight, cooking time, dry seed volume, dry seed density and swelling capacity were highly positively correlated with hundred seed weight.

However, bold seeded types registered more volume expansion percentage (> 50%) than small seeded types excluding the genotype, RM 20-13. Moreover, the bold seeded types are soft and palatable compared to others, which may be suitable for snack and sundal purpose. Hence, based on the consumer preference, the small and medium seeded types can be recommended for sambar and dhal purpose and bold seeded types for snacks and sundal purposes.

FUTURE SCOPE

Grain quality traits like hydration capacity, swelling capacity, hydration index, swelling index, water absorption percentage, volume expansion percentage, etc., plays a significant role in the improvement of grain quality. The market value of the mungbean can be increased by improving the grain quality as consumer preferences are mostly based on the grain quality traits. The superior genotypes identified for different quality traits can be exploited in the hybridization programme. It is believed that more importance will be given to grain quality traits in the future breeding programme.

Acknowledgement. The first author is grateful to the Tissue culture lab, Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai for providing the necessary facilities to carry out the research work.

Conflict of Interest. None.

REFERENCES

Afzal, M. A., Bashir, M. M., Luna, N. K., Bakr, M. A., & Haque, M. M. (2003). Relationship between seed size, protein content and cooking time of mungbean [*Vigna radiata* (L.) Wilczek] seeds. *Asian Journal of Plant Sciences*.

Burton, G. W. (1952). Quantitative inheritance in grasses. *Pro VI Int Grassl Cong, 1952*, 277-283.

Dewey, D. R., & Lu, K. (1959). A correlation and path coefficient analysis of components of crested wheatgrass seed production 1. *Agronomy journal*, *51*(9), 515-518.

Enyiukwu, D. N., Chukwu, L. A., & BASSEY, I. N. (2020). Nutrient and anti-nutrient compositions of cowpea (*Vigna unguiculata*) and mung bean (*Vigna radiata*) seeds grown in humid Southeast Nigeria: A comparison. *International Journal of Tropical Drylands*, *4*(2).

Ghosh, A., & Panda, S. (2006a). Variation, association and path analysis of grain quality attributes in blackgram (*Vigna mungo* L. Hepper). *Legume Research*, *29*(1), 43-47.

Ghosh, A., & Panda, S. (2006b). Pattern of variability, character association and path analysis for grain quality in mungbean (*Vigna radiata* L. Wilczek). *Legume Research-An International Journal*, *29*(2), 114-117.

Gupta, N., Srivastava, N., &Bhagyawant, S. S. (2018). Vicilin—A major storage protein of mungbean exhibits antioxidative potential, antiproliferative effects and ACE inhibitory activity. *PLoS One*, *13*(2), e0191265.

Honnappa, D. M., Hosamani, M., Babu, U., & Archana, K. A. (2018). Characterization, association and path analysis studies of different cooking quality/physicochemical parameters in green seeded chickpea genotypes. *Journal of Pharmacognosy and Phytochemistry*, *7*(6), 2027-2033.

Hou, D., Yousaf, L., Xue, Y., Hu, J., Wu, J., Hu, X., & Shen, Q. (2019). Mung bean (*Vigna radiata* L.): bioactive polyphenols, polysaccharides, peptides and health benefits. *Nutrients*, *11*(6), 1238.

Johnson, H. W., Robinson, H. F., & Comstock, R. E. (1955). Estimates of genetic and environmental variability in soybeans 1. *Agronomy journal*, *47*(7), 314-318.

Kumar, S., & Pandey, G. (2020). Biofortification of pulses and legumes to enhance nutrition. *Heliyon*, *6*(3), e03682.

Lenka, D., & Mishra, B. (1973). Path coefficient analysis of yield in rice varieties. *Indian J. Agric. Sci*, *43*(4), 376.

Lush, J. L. (1940). Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics. *Journal of animal science*, *1940*(1), 293-301.

Mekkaranikarthil Sudhakaran, S., & Bukkan, D. S. (2021). A review on nutritional composition, antinutritional components and health benefits of green gram (*Vigna radiata* (L.) Wilczek). *Journal of Food Biochemistry*, *45*(6), e13743.

Nair, R., & Schreinemachers, P. (2020). Global status and economic importance of mungbean. In *The mungbean genome* (pp. 1-8). Springer, Cham.

Neyaz, A., & Bajpai, G. C. (2002). Physical and cooking qualities of pigeonpea and their correlations. *Legume Research-An International Journal*, *25*(3), 192-195.

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Santhan, R. H., & Shivshankar, G. C. (1978). Cooking characteristics of Horse grain. *Indian J Agric Sci*, *48*, 399-401.

Sastry, D. V. S. S. R., Upadhyaya, H. D., & Srinivas, T. R. (2019). Variation for seed physical and hydration properties of chickpea (*Cicer arietinum* L.) mini core collection and their relevance to conservation and utilization. *Plant Genetic Resources*, *17*(4), 311-324.

Sethi, S., Samuel, D. V. K., & Lal, K. (2008). Inter-Relationship Between Cooking Time and Some Physico-Chemical Characteristics in Pigeon Pea (*Cajanus cajan*) Genotypes. *Journal of Agricultural Engineering*, *45*(2), 62-65.

Sheoran, O. P., Tonk, D. S., Kaushik, L. S., Hasija, R. C., & Pannu, R. S. (1998). Statistical software package for agricultural research workers. *Recent advances in information theory, statistics & computer applications by DS Hooda & RC Hasija Department of Mathematics Statistics, CCS HAU, Hisar*, 139-143.

Singh, T. (2016). Estimation of genetic parameters and character associations for yield and quality traits in chickpea. *Indian Journal of Agricultural Research*, *50*(2), 117-121.

Sivasubramanian, S., & Madhavamenon, P. (1973). Genotypic and phenotypic variability in rice. *Madras Agric. J*, *60*(9-13), 1093-1096.

Srivastava, A. K., Dixit, G. P., Nisar, M., & Singh, N. P. (2020). Genetic Variability and Inter-Relationships Among Grain Physical and Hydration Traits in Chickpea. *Legume Research-An International Journal*, *1*, 4.

Veni, K., Murugan, E., & Radhamani, T. (2015). Correlation and path co-efficient analysis of grain quality attributes in Black gram (*Vigna mungo* L. Hepper). *Electronic Journal of Plant Breeding*, *6*(3), 715-722.

How to cite this article: Jenifer Sylvia J., Murugan E., Muthuramu S., Renuka R. and Vellaikumar S. (2022). Genetic Variability and Inter-Relationships among Grain Physical Quality Traits in Mungbean (*Vigna radiata* L. Wilczek). *Biological Forum – An International Journal*, *14*(3): 732-740.