LR-5089
[1-8]

RESEARCH ARTICLE Legume Research- An International Journal

Development of Mungbean Genotypes for Shattering Tolerance and Correlation Analysis with Biochemical and Morphological Factors Governing Pre Harvest Sprouting

Suma Mogali[1], N.K. Biradar Patil[1], H. Ranjita[1], Gurupad Balol[1], Lalita Jaggal[1] 10.18805/LR-5089

ABSTRACT

Background: Most of the mungbean genotypes are prone to shattering. The indeterminate flowering habit of this crop leads to a spread of flowering and pod maturity on a single plant over the entire reproductive phase. Consequently, pods which develop at the earliest flower may shatter prior to 100% pod maturity. Sometimes losses due to pre-harvest sprouting will be as high as 60-70%. High yielding varieties developed/identified in recent years, despite their high yield potential, could not increase/stabilize the yields of this crop due to lack of resistance to pre-harvest sprouting. Therefore, an attempt was essentially made to develop tolerant varieties to pre-harvest sprouting in the current investigation.

Methods: The F_2 (Healthy and well dried) seeds derived from the crosses DGGV-2 × Pant Moong-1 were irradiated with 60 kR gamma rays for the creation of desirable variability. The gamma rays irradiated seeds were sown in during *kharif*-2017 along with their respective checks to grow the F_2M_1 generation. Further advanced to F_2M_2. The individual plants were critically observed at maturity for morphological traits *viz.,* small pod beak length and angle, thick pod wall and hard seededness that determine the tolerance to PHS. The mutant lines were compared with the parental lines *viz.*, shattering tolerant variety Pant Moong-1 as well as susceptible variety DGGV2. The putative mutants selected and tagged in F_2M_2 and the seeds were harvested separately and forwarded to develop the F_2M_3 mutant population (1000 plants) in summer-2018. The seeds from F_2M_3 generation were harvested on individual plant basis and were sown. 806 progenies were sown in augmented design along with the checks in each block during *kharif* 2019. Thus from the population of 24812 such derived plants, genotypes with small pod beak and angle, thick pod wall, hard seededness and higher epicuticular wax and lignin content were isolated in F_2M_3 and F_2M_4. Further a total of 49 advanced breeding lines along with a known shattering susceptible check were studied for the morphometric and biochemical parameters governing the pre harvest sprouting.

Result: Lower PHS was recorded in DGGV-79 (0.02%), DGGV-125 (0.02%) and DGGV 195 (0.91%). Higher phenol content was recorded in DGGV-125 (9.43 mg GA eq /g) and DGGV-79 (9.37 mg GA eq /g). Higher lignin content was recorded in DGGV-125 (6.42 mg/g) and DGGV-79 (6.10 mg GA eq /g). Further correlation analysis revealed that negative correlation of PHS was observed for epicuticular wax (r= -0.983), phenol (r= -0.892), lignin content (r= -0.981) and hard seed percentage (r= -0.942). Significant negative correlation was observed between PHS and pod wall thickness (r= -0.570). Pod beak length recorded highly significant positive correlation (r= 0.911) to PHS. Genotypes with inherent tolerance to seed shattering hold a promise to minimize yield losses due to viviparous germination.

Key words: Biochemical parameters, Correlation analysis, Pre-harvest, Sprouting (PHS), Morphometric traits.

INTRODUCTION

A prolonged rainy period at maturation often results in poor seed quality due to fungal infestation, sprouting of seeds within pods and discolouration of seeds. Premature sprouting is a serious problem in mungbean in the tropics. Small pod beak and angle, thick pod wall, low rate of moisture absorption by pod wall, hard seededness and higher cuticular wax content on pod wall were found to impart resistance to pre-harvest sprouting (Naidu *et al.*, 1996). A moderate level (15-20 days) of hard seededness may be useful in contributing to tolerance to weather damage. Transient hard-seededness is common in mungbean; the level of hard seededness in mungbean has been observed to be the highest at harvest and it declines with storage. It has been observed that the hard-seeded character in the wild progenitor of mungbean, V. *radiata* var. sublobata, is governed by a dominant gene Hd_1Hd_1. Most of the mungbean genotypes are prone to shattering. The indeterminate flowering habit of this crop leads to a spread

[1]AICRP on MULLaRP, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad-580 001, Karnataka India.

Corresponding Author: Suma Mogali. AICRP on MULLaRP, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad-580 001, Karnataka India. Email: sumamogali@gmail.com

How to cite this article: Mogali, S., Patil, N.K.B., Ranjita H., Balol G. and Jaggal, L. (2023). Development of Mungbean Genotypes for Shattering Tolerance and Correlation Analysis with Biochemical and Morphological Factors Governing Pre Harvest Sprouting. Legume Research. DOI: 10.18805/LR-5089

Submitted: 14-12-2022 **Accepted:** 03-07-2023 **Online**: 02-12-2023

of flowering and pod maturity on a single plant over the entire reproductive phase. Consequently, pods which develop at the earliest flower may shatter prior to 100% pod maturity. To avoid shattering, often the pods are hand-picked. Therefore, it may be desirable to identify donors and incorporate gene(s) for non-shattering. ‘Pant Moong-1’ is tolerant to shattering. Its harvesting can be delayed by 7-10 days, so as to allow the maturity of pods from second flush of flowers. Shattering is completely dominant to the non-shattering and probably conditioned by a single gene. The long duration cultivars with more reproductive flushes would give more stable yields because flowering would be continued over the longer period. However, such cultivars would require additional pickings and would be prone to lodging, shattering and sprouting.

The average productivity of this crop is low and uncertain due to neglected management and poor adoption of the production technology due to the risk of pre-harvest sprouting. Sometimes losses due to pre-harvest sprouting will be as high as 60-70%. (Sharma *et al.,* 2018). High yielding varieties developed/identified in recent years, despite their high yield potential, could not increase/stabilize the yields of this crop due to lack of resistance to pre-harvest sprouting. Therefore an attempt was essentially made to develop tolerant varieties to pre-harvest sprouting in the current investigation.

MATERIALS AND METHODS

Experimental site

A series of field experiments spanned over six years (2015-2020) were conducted at F block, AICRP on MULLaRP, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India, geopositioned at $15^{o}26'$ North latitude, $75^{o}07'$ East longitude and at an altitude of 750 m above the Mean Sea Level and located in the North Western transitional agro-climatic zone of Karnataka, which receives an average annual rainfall of 718 mm well distributed over the season (Fig 1). The average temperature and relative humidity ranged from 18 to 37^{o}C and 40 to 85 per cent respectively. The ill - distributed rainfall during *kharif* 2019 was 892.2 mm, as against average rainfall of 718.23 mm. The maximum and minimum temperature during the crop season was 30.1^{o}C and 18.3^{o}C respectively. Similarly, the relative humidity ranged from 57 to 96 per cent as against normal RH of 54.12 to 88.86 per cent (Table 1). Due to high rain fall in August (462.2 mm) during pod development and maturity coupled with higher humidity across two years (*kharif* 2019 and 2020) weather parameters were highly conducive for viviparous germination, resulting in higher percent of pre harvest sprouting.

Experimental material and methodology

The F_2 (Healthy and well dried) seeds derived from the crosses DGGV-2 x Pant Moong-1 were irradiated with 60 kR gamma rays for the creation of desirable variability. The gamma rays irradiated seeds were sown in during *kharif*-2017 along with their respective checks to grow the F_2M_1 generation. Further advanced to F_2M_2. The individual plants were critically observed at maturity for morphological traits *viz.,* small pod beak length and angle, thick pod wall and hard seededness that determine the tolerance to PHS. The mutant lines were compared with the parental lines *viz.,* shattering tolerant variety Pant Moong-1 as well as susceptible variety DGGV2. The putative mutants selected and tagged in F_2M_2 and the seeds were harvested separately and forwarded to develop the F_2M_3 mutant population (1000 plants) in *summer*-2018.

Fig 1: View of experimental plot.

Table 1: Heavy rainfall and high humidity favouringviviparous germination during *kharif* 2019.

STD meteorological Week	TempMax	TempMin	Rainfall	Rainy Days	RH1	RH2
Jun 4-Jun 10	35.5	22.2	6.8	1	85	43
Jun 11-Jun 17	30.7	21.6	14.9	2	91	63
Jun 18-Jun 24	30.4	21.2	32.4	2	90	63
Jun 25-Jul 1	26.6	20.4	86.6	2	94	72
Jul 2-Jul 8	27.3	20.3	82.0	7	93	81
Jul 9-Jul 15	26.9	20.1	42.6	3	92	73
Jul 16-Jul 22	29.2	20.3	22.0	3	92	67
Jul 23-Jul 29	25.6	20.4	41.0	2	94	84
Jul 30-Aug 5	24.7	19.9	150.6	7	96	83
Aug 6-Aug 12	24.9	20.1	277.2	6	93	81
Aug 13-Aug 19	27.4	20.9	15.2	1	94	67
Aug 20-Aug 26	28.1	20.5	13.8	3	90	69
Aug 27-Sep 2	26.8	20.8	10.6	1	93	79

The seeds from F_2M_3 generation were harvested on individual plant basis and were sown 806 progenies were sown in augmented design along with the checks in each block during *kharif* 2019. Thus from the population of 24812 such derived plants, genotypes with small pod beak and angle, thick pod wall, hard seededness and higher epicuticular wax and lignin content were isolated in F_2M_3 and F_2M_4. Further a total of 49 advanced breeding lines along with a known shattering susceptible check were studied for the morphometric and biochemical parameters governing the pre harvest sprouting.

Pod beak length

The pod beak length was measured from five randomly selected plants from each genotype from the base of the beak to the tip of the beak as per the procedure given by Cheralu *et al.* (1999). The mean value was expressed as pod beak length.

Pod wall thickness

The pod wall thickness was measured from 10 randomly selected plants from each genotype with the help of digital micrometers per the procedure given by Cheralu *et al.* (1999). The mean value was expressed as pod wall thickness.

Pod pubescence

Presence or absence of hairiness or pubescence on pods was recorded by following the DUS guidelines of PPV and FRA.

Epicuticular wax

The epicuticular wax content of the pod wall was estimated by the gravimetric method. Cheralu *et al.* (1999).

Phenolic content

It was determined by Folin-Ciocalteu's method. The TPC was expressed as mg gallic acid equivalents (GA eq) per g of extract (Arun *et al.,* 2016).

Lignin content

Protein-free cell wall samples of green gram (20 mg) were used to estimate lignin content (Marwanto, 2007).

Percentage of sprouted pods per plant per plot

The number of plants per plot in which the sprouted pods were counted to the total number of plants per plot and the value was expressed.

Percentage of sprouted pods per plant

The number of pods with sprouted pods per plant to total number of pods per plant was counted from five randomly selected and tagged plants and the mean value was worked out and expressed as percentage of sprouted pods per plant.

Statistical analysis

An augmented design (Federer, 1956), which holds considerable promise for evaluation of breeding materials, was used in this study. Augmented design incorporates the provision of accommodating single replication of all treatments by spreading it over all the blocks (b), while a set of checks (c), were replicated in each block. Randomization was done in such a way that all the checks (c) and a part of test genotypes fall only once in each block. Equal numbers of test genotypes were planted in each block to facilitate statistical analysis. The data recorded on each of five random plants for different quantitative traits were averaged and analyzed using R software version 4.2.1 and Excel.

RESULTS AND DISCUSSION

The analysis of variances revealed significant variability for most of the characters The mutant progenies of the cross derivative of DGGV-2 × Pant Moong-1 have shown significant variation for the characters like pod beak length and angle, pod wall thickness, rate of moisture absorption by pod wall, hard seededness and cuticular wax content on pod wall. The pod beak length differed significantly due to the genotypes. longer pod beak length was recorded in DGGV-61 (0.338 cm), followed by DGGV-1 (0.335 cm). While, shorter pod beak length was recorded by DGGV-125 (0.119 cm) which was on par with DGGV-73 (0.120 cm), DGGV-65 (0.123 cm) and followed by DGGV-10 (0.133 cm).

In the month of August-2019, a total of 443 mm of rainfall was received as against the normal rainfall of 101.73 mm, followed by sunshine and favourable temperature *i.e.*, alternate wetting and drying process. This disrupted the crop during its grand growth period and led to pre-harvest sprouting of pods on mother plants.

DGGV 65 (0.123 cm) recorded shorter pod beak length. In general, with increase in pod beak length, the PHS percentage increased at varied level among the genotypes as the surface area increased with longer pod beak length which helped the pod to absorb more rain water leading to higher PHS. Similar observation with increased PHS due to increase in pod beak length in green gram was earlier reported by Cheralu *et al.* (1999).

The pod wall thickness showed significant effect due to genotypes. Maximum thicker pod wall was recorded in DGGV-79 (0.654 μm) and it was on par with DGGV-67 (0.635 μm), DGGV-73 (0.631 μm) and DGGV-66 (0.628 μm), followed by DGGV-21 (0.585 μm). Whereas, thinner pod wall was recorded by DGGV-2 (0.341 μm), which was on par with DGGV-82 (0.348 μm), Kombhesaru (0.356 μm), DGGV-87 (0.356 μm), DGGV-81 (0.358 μm) and DGGV-213-1 (0.365 μm), followed by DGGV-184 (0.443 μm).

Influence of biochemical parameters associated with pre-harvest sprouting

Phenol content

There was significant difference in the phenol content among the genotypes, higher phenol content was recorded in DGGV-125 (9.43 mg GA eq/g) which was on par with DGGV-79 (9.37 mg GA eq/g) and followed by DGGV-73 (8.94 mg GA eq/g), while, lower phenol content was recorded in DGGV-

96 (4.03 mg GA eq/g) and followed by DGGV-109 (4.37 mg GA eq/g) (Fig 2a).

Lignin content

While comparing the lignin content among the genotypes. Significantly, higher lignin content (6.42 mg/g) was recorded in DGGV-125, followed by DGGV-79 (6.10 mg/g) and lower lignin content (3.90 mg/g) was recorded in DGGV-72, followed by Kombhesaru (3.99 mg/g) (Fig 2a).

Pod epicuticular wax

The pod epicuticular wax differed among the genotypes. Significantly, higher pod epicuticular wax (13.90 $\mu g/cm^2$) was recorded in DGGV 81, followed by DGGV-125 (13.03 $\mu g/cm^2$) and DGGV-73 (12.85 $\mu g/cm^2$). Lesser pod epicuticular wax was recorded by Kombhesaru (0.95 $\mu g/cm^2$), followed by DGGV-109 (1.28 $\mu g/cm^2$) (Fig 2b).

The pod wall thickness differed significantly among the genotypes. The thicker pod wall was recorded by DGGV-79 (0.654 μm), while thinner pod wall was observed with DGGV-2 (0.341 μm). The thicker pod wall protects the seeds from PHS by avoiding or reducing the water entry into the pods. Cheralu *et al.* (1999) and Anupama *et al.* (2012) also observed increase in PHS with decreased pod wall thickness. However, pod wall thickness alone may not account for minimum imbibition of water by pods. Higher wax content in pod wall of PHS tolerant genotypes might restrict water to come in contact with the seeds causing failure of seed germination and thereby making the genotypes PHS tolerant. So, significantly, higher epicuticular wax was recorded in DGGV-79 (13.90 $\mu g/cm^2$) and lesser epicuticular wax (0.95 $\mu g/cm^2$) was recorded in Kombhesaru (Fig 1). Higher epicuticular wax on the pod wall induces the im-permiability to water on its surface and avoids the occurrence of PHS on mother plant. The similar findings were reported by Tekorny *et al.* (1980) in soyabean and by William (1984) in mungbean. Baker (1974) also reported that an increase in the temperature, humidity and rainfall mainly reduces wax content.

Percentage of sprouted pods per plant per plot

The percentage of sprouted pods per plant per plot differed within the genotypes. Significantly, higher percentage of sprouted pods per plant per plot was recorded in Kombhesaru (34.27%), followed by DGGV-109 (29.26%) and lower percentage of sprouted pods per plant per plot was recorded in DGGV-79 (0.02%) and DGGV-125 (0.03%) which showed resistance to sprouting.

Percentage of sprouted pods per plant

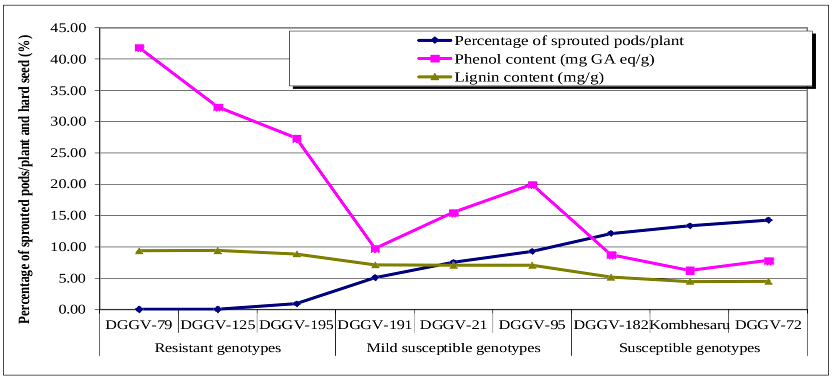
The percentage of sprouted pods per plant varied among genotypes. Significantly, higher percentage of sprouted pods per plant (14.25%) was recorded in DGGV-72 and followed by Kombheasru (13.36%) and lower percentage of sprouted pods per plant (0.01%) was recorded in DGGV-79 and DGGV-125 (0.02%), followed by DGGV-195 (0.9%) (Fig 2c).

Non-significant positive correlation (r= 0.453) with pod length was observed. Significant negative correlation with pod wall thickness was recorded (r= -0.570) and significant positive correlation was recorded for pod beak length (r= 0.759). Sprouted pods per plant showed significantly higher positive correlation (r= 0.946) and other parameters showed highly significant negative correlation were, pod epicuticular wax (r= -0.983), phenol content (r= -0.892), lignin content (r= -0.981) and hard seed percentage (r= -0.942). Similarly, the percentage of sprouted pods per plant noted significant and non-significant correlation with other parameters. There was non-significant negative correlation with pod wall thickness was observed (r= -0.437), significant positive correlation was recorded in pod length (r= 0.623). Pod beak length showed highly significant positive correlation (r= 0.911) and highly significant negative correlation was recorded in pod epicuticular wax (r= -0.980), phenol content (r= -0.868), lignin content (r= -0.978) and hard seed percentage (r= -0.956) (Table 2).

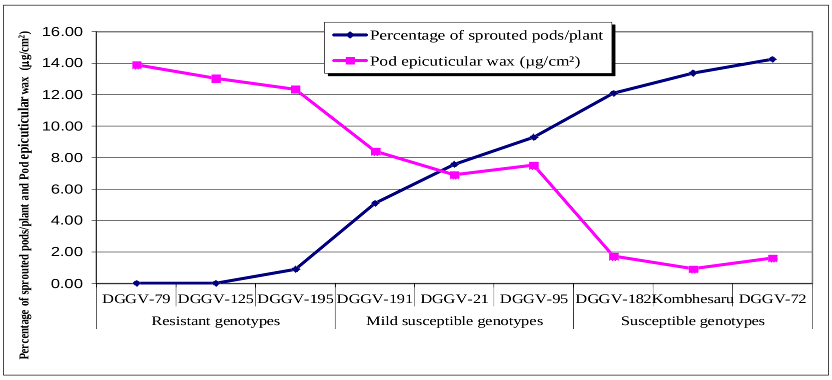
Influence of biochemical factors on preharvest sprouting

The phenol and lignin content varied significantly due to genotypes. The higher phenol content was recorded in DGGV-125 (9.43 mg/g) and lower phenol content was recorded in DGGV- 96 (4.03 mg/g). Similarly, higher lignin content was recorded in DGGV-125 (6.42 mg/g) and lower lignin content (3.90 mg/g) was recorded in DGGV-72.

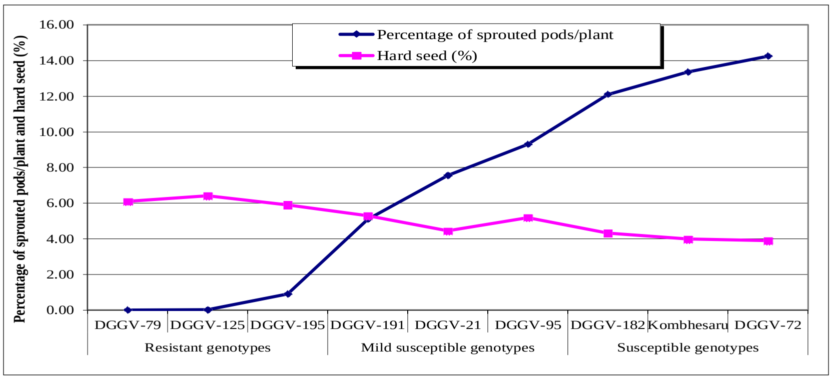
The desirable plants with less than 5 per cent PHS were characterized by morphological and biochemical indicators. Lower PHS was recorded in DGGV-79 (0.02%), DGGV-125 (0.02%) and DGGV 195 (0.91%). Some genotypes showed resistant to pre-harvest sprouting mainly due to shorter pod beak length, thicker pod wall, higher pod epicuticular wax, phenol, lignin content and more number of hard seeds lead to development of hydrophobic thick coat of pod and seed, which, possess impermeable nature for water absorption and prevent pre-harvest sprouting of pods on mother plant under heavy and continues rainfall condition. Similar observation were reported by Cheralu *et al.* (1999). From the correlation analysis it was observed that some of the morphological and biochemical factors were correlated with pre harvest sprouting. Non-significant positive correlation (r= 0.453) with pod length was observed. Significant negative correlation with pod wall thickness was recorded (r= -0.570) while significant positive correlation was recorded for pod beak length (r= 0.759). Sprouted pods per plant showed significantly higher positive correlation (r= 0.946) and other parameters which showed highly significant negative correlation incuded pod epicuticular wax (r= -0.983), phenol content (r= -0.892), lignin content (r= -0.981) and hard seed percentage (r= -0.942). Pod beak length showed highly significant positive correlation (r= 0.911) (Fig 3). The desirable plants with less than 5 percent pre PHS were characterized by these morphological and biochemical indicators. Lower PHS was recorded in genotypes DGGV-79 (0.02%), DGGV-125 (0.02%) and DGGV 195 (0.91%)



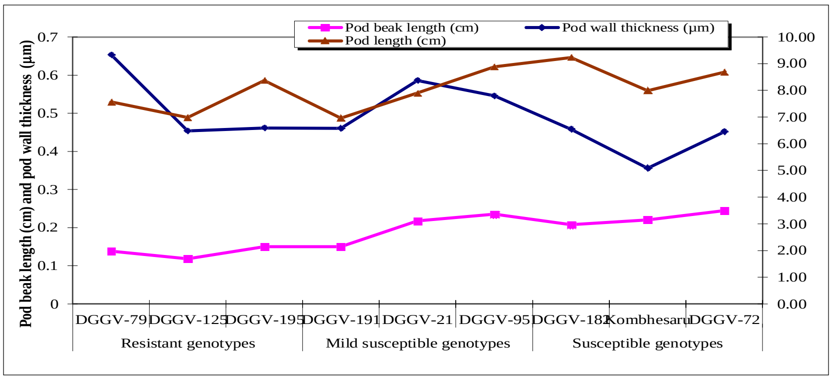
a): Effect of phenol and lignin content on pre-harvest sprouting in green gram genotypes.



b): Effect of pod epicuticular wax on pre-harvest sprouting in greengram genotypes.



c): Effect of hard seed on pre harvest sprouting in greengram genotypes.



d): Pod beak length, pod wall thickness and pod length in greengram genotypes.

Fig 2: Influence of Biochemical and Morphological parameters on Pre harvest sprouting in Mungbean.

Table 2: Correlation analysis of biochemical and morphological indicators of pre harvest sprouting in Mungbean.

	Percentage of shattered pods/plant /plot	Percentage of shattered pods/plant	Pod length (cm)	Pod beak length (cm)	Pod wall (µm)	Pod epicuticular wax (µg/cm²)	Phenol content (mg GA eq/g)	Lignin content (mg/g)
Percentage of sprouted pods/plant/plot	1							
Percentage of sprouted pods/plant	0.946**	1						
Pod length (cm)	0.453	0.623*	1					
Pod beak length (cm)	0.759*	0.911**	0.721*	1				
Pod wall thickness (µm)	-0.570*	-0.437	-0.069	-0.150	1			
Pod epicuticular wax (µg/cm2)	-0.983**	-0.980**	-0.563*	-0.830**	0.534*	1		
Phenol content (mg GA eq/g)	-0.892**	-0.868**	-0.365	-0.702*	0.618*	0.906**	1	
Lignin content (mg/g)	-0.981**	-0.978**	-0.534*	-0.826**	0.539*	0.993**	0.911**	1

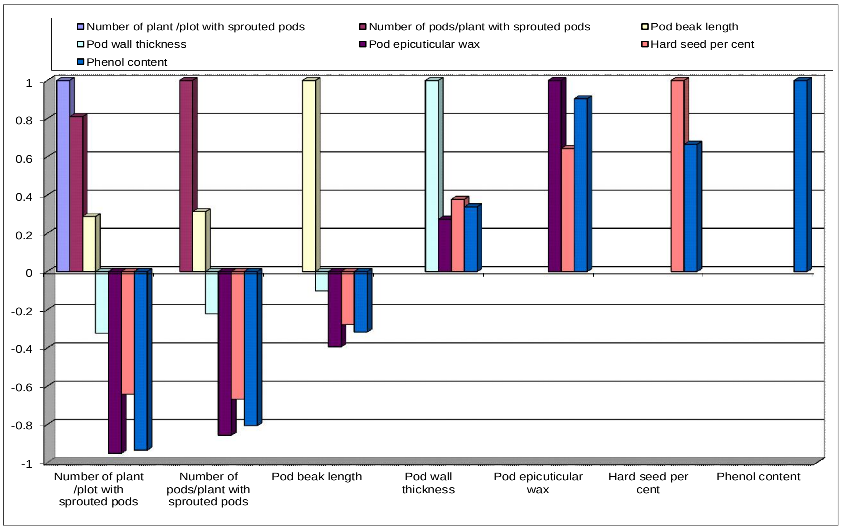


Fig 3: Correlation analysis of biochemical and morphological indicators of pre harvest sprouting.

hence testifying the observed correlations conferring shattering tolerance, while DGGV-191 and DGGV-95 were mild susceptible to PHS, DGGV-72 and Kombhesaru were susceptible to pre-harvest sprouting (Fig 4).

Validation of morphological and biochemical parameters governing tolerance to pod shattering in advanced breeding lines (ABLs)

Validation and confirmation of morphological and biochemical parameters conferring tolerance to shattering were done based on the study conducted during *kharif* 2020 was done during *kharif* 2021 with the same set of genotypes. DGGV 125 (0.114 cm) recorded a shorter pod beak length, which was obtained from DGGV-2 X SML-1815. In general, with an increase in pod beak length, the PHS percentage increased at a varied level among the genotypes as the surface area increased with longer pod beak length which helped the pod to absorb more rainwater leading to higher PHS. A similar observation with increased PHS due to an increase in pod beak length in green gram was earlier reported by Cheralu *et al.* (1999) and Ranjitha and Patil (2020).

The pod wall thickness differed significantly among the genotypes. The thicker pod wall was recorded by DGGV-79 (0.648 µm), while the thinner pod wall was observed with DGGV-72 (0.418 µm). DGGV-79 was derived from a mutant of IPM 2-17 22-1 with good seed yield (8.00 g) and lower pod beak length (0.126 cm) (Fig 2d). Whereas DGGV-72 is susceptible to shattering. The thicker pod wall protects the seeds from PHS by avoiding or reducing the water entry into the pods. Cheralu *et al.* (1999) and Anupama *et al.* (2012) also observed an increase in PHS with decreased pod wall thickness. However, pod wall thickness alone may not account for the minimum imbibition of water by pods. Higher wax content in the pod wall of PHS tolerant genotypes might restrict water to come in contact with the seeds causing failure of seed germination and thereby making the genotypes PHS tolerant. Higher epicuticular wax on the pod wall induces the im-permeability to water on its surface and

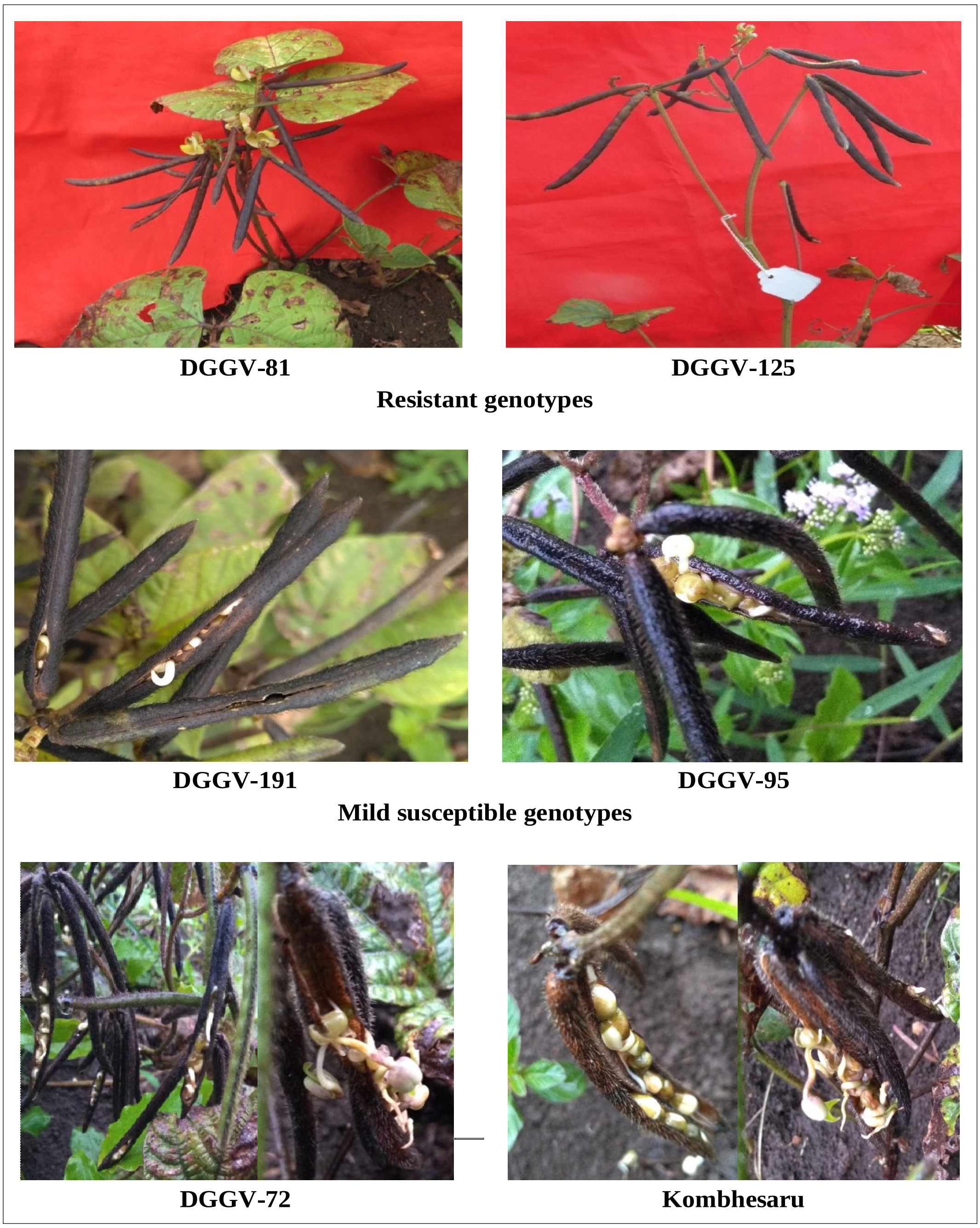


Fig 4: Pre-harvest sprouting in different Susceptible genotypes.

avoids the occurrence of PHS on the mother plant. Similar findings were reported by Tekorny *et al.* (1980) in soybean and by William (1984) in mungbean.

Significantly, higher phenol content was recorded in DGGV-125 (9.38 mg GA eq/g), whereas, lower phenol content was recorded in DGGV-72 (4.4 mg GA eq/g). Similarly, the lignin content also varied among genotypes. DGGV-125 (6.34 mg/g) recorded higher lignin content and lower lignin content was recorded in DGGV-72 (3.86 mg/g). This variation may be due to the genetic make of the genotype, which varies with individual genotype. These biochemical contents influenced the PHS significantly, by inducing chemical inhibitors in resistant genotypes (Ranjita and Patil 2020). The presence of increased lignin and hydrophobic phenols in the mesophyll layer of the hilar area and the palisade layer of the seed coat was previously observed by Marback and Mayer (1974). The presence of phenolic compounds in seeds may be the actives responsible for the species' deep physiological dormancy and seed viability preservation (Inacio *et al.,* 2013). In a study conducted by

Weidner *et al.* (1999) cultivars susceptible to sprouting displayed higher germination percentages than those resistant to sprouting. The majority of phenolic acids were found in the form of soluble esters. For all species examined, the levels of phenolic acids liberated from soluble esters and the total phenolic acid contents in caryopses showing shallow dormancy were higher than in those showing deeper dormancy. Cellulose ensures the toughness of cell walls, while lignin, an important phenolic compound with a complex structure in plants, enhances the hydrophobicity and hardness of cell walls, physical strength and water-conducting capacity and other important functions in the plant body (Kuai *et al.,* 2016).

Shattering tolerance was recorded in DGGV-79 (0.03 percent), DGGV-125 (0.04 per cent) and DGGV 195 (0.91 percent). The genotype DGGV-125 was derived from DGGV-2 X SML-1815 with a good seed yield (5.64 g) and pod beak length of 0.114 cm. DGGV-195 was obtained from a mutant of VGG rul 4-2 with seed yield of 6.34 g and lower pod beak length (0.13 cm). Some genotypes showed resistance to pod shattering mainly due to shorter pod beak length, thicker pod wall, higher pod epicuticular wax, phenol, lignin content and a greater number of hard seeds lead to the development of hydrophobic thick coat of pod and seed, which, possess impermeable nature for water absorption and prevent shattering of pods on mother plant under heavy and continues rainfall condition. A similar observation was reported by Cheralu *et al.* (1999). Genotypes with inherent tolerance to seed shattering hold a promise in profitable mungbean cultivation.

CONCLUSION

Pre-harvest sprouting is a complex trait and is controlled by many genes showing significant interaction with the environment. In this study,mungbean genotypes DGGV-79 DGGV-125 andDGGV 195 with less than five percent of PHS have been identified. Resistance to pre-harvest sprouting is mainly due to shorter pod beak length, thicker pod wall, higher pod epicuticular wax, phenol, lignin content and more number of hard seeds which have led to development of hydrophobic thick coat of pod and seed, which, possess impermeable nature for water absorption and prevent pre-harvest sprouting of pods on mother plant under heavy and continuous rainfall coupled with high humidity coupled with intermittent sunshine conditions. Hence these genotypes with inherent tolerance to seed shattering hold a promise in profitable mungbean cultivation.

Conflict of interest: None.

REFERENCES

Ahmad, R., Khulbe R.K. and Roy, D. (2014). Evaluation of mungbean [*Vigna radiata* (L.) Wilczek] germplasm for pre-harvest sprouting tolerance. Legume Res. 37(3): 259-263.

Anupama, S., Khulbe, R.K. and Panwar, R.K. (2012). Evaluation of urdbean (*Vignamungo*) germ plasm for pre-harvest sprouting tolerance. J. Food Legumes. 25(3): 183-186.

Arun, S., Deepakraj, S., Vadive, V. and Brindha, P. (2016). Recovery of polyphenols from the pods of green gram and black gram and evaluation of their antioxidant activity. Int. J. Chem. Sci. 14(4): 2658-2672.

Baker E.A. (1974). The influence of environment of leaf wax development in *Brassica oleracea*. New Phytol. 73: 955-966.

Cheralu, C., Satyanarayana. A., Kulkarni. N., Jagdishwar, K. and Reddy M.S. (1999). Combining ability analysis for resistance to pre-harvest sprouting in mungbean [*Vigna radiata* (L.) Wilczek]. Ind. J. Genet. 59(4): 465-472.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures in Agricultural Research (2nd edition), Cambridge University, New York, pp. 680.

Inacio, M.C., Moraes, R.M., Mendonça, P.C., Morel, L.J., França, S.C., Bertoni, B.W. and Pereira, A.M. (2013). Phenolic compounds influence seed dormancy of *Palicourea rigida* HBK (Rubiaceae), a medicinal plant of the Brazilian Savannah.

Kuai, J., Sun, Y., Liu, T., Zhang, P., Zhou, M., Wu, J. and Zhou, G. (2016). Physiological mechanisms behind differences in pod shattering resistance in rapeseed (*Brassica napus* L.) varieties. PloS one. 11(6): p. e0157341.

Marbach, I. and Mayer, A.M. (1974). Permeability of seed coats to water as related to drying conditions and metabolism of phenolics. Plant physiology. 54(6): 817-820.

Marwanto. (2007). Relationship between seed coat lignin content and seed coat characteristics in mungbean. J. Indonesian Agril. Sci. 9: 6-11.

Naidu, N.V., Seenaiah, P. and Satyanarayana, A. (1996). Mechanism of resistance to pre harvest sprouting in mungbean. Int. Symp. Pulses Res. 140-141.

Paul, D., Chakrabarty, Dikshit, H.K. and Singh, Y. (2019). Variation for hard seededness and related seed physical parameters in mungbean [*Vigna radiata* (L.) Wilczek]. Ind. J. Genet. 78(3): 333-341.

Ranjitha H. and Patil, B. (2020). Association of pod and biochemical parameters with pre-harvest sprouting in greengram (*Vigna radiata* L.) genotypes. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Sharma, A.A., Sarma, M. and Ramchiary, N. (2018). Genetic variability and character association in soybean germplasm for pre-harvest sprouting tolerance and associated traits. Int. J. Genet. 10: 390-39.

Tekorny, D.M., Egli, D.B. and Philips, A.D. (1980), Effect of field weathering on the variability and vigour of soybean. Seed Agron. J. 72:748-753.

Weidner, S., Amarowicz, R., Karamać, M. and Dąbrowski, G. (1999). Phenolic acids in caryopses of two cultivars of wheat, rye and triticale that display different resistance to pre-harvest sprouting. European Food Research and Technology. 210: 109-113.

William, R.W. (1984). Plant Breeding for Seed Production and Quality. Proc. Seed Res. Conference, Lawes. 191-197.