Genetic Variability and Correlation Studies for Pre-harvest Sprouting Tolerance and Associated Traits in Soybean [Glycine max L. Merrill.]

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Authors' contributions
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ABSTRACT

Evaluation of a set of 65 diverse genotypes of soybean was carried out for their pre-harvest sprouting (PHS) tolerance in a field study during kharif 2019. Percentage of pods ruptured by sprouting seed (PPR) was used as a measure of pre-harvest sprouting tolerance. It ranged from 0-5.8% among the genotypes. High estimates of genotypic (GCV) and phenotypic coefficients of variation (PCV) were recorded for the percentage of pods ruptured by sprouting seed (PPR) indicating the presence of wider variability over which selection can be effective. High heritability coupled with high genetic advance as percent mean was recorded for number of pods ruptured by sprouting seed per plant and PPR. The phenotypic character association revealed a significant negative correlation of PPR with pod wall thickness, number of pods per plant, and number of clusters per plant. Path coefficient analysis revealed number of pods per plant, plant height, and pod wall thickness have a negative influence on pre-harvest sprouting.
1. INTRODUCTION

Soybean (*Glycine max*) is gaining importance as a major oilseed crop in India terms of area, production and economic value, occupying an area of 10.47 million hectares with production and productivity of 10.98 million tonnes and 1049 kg/ha respectively. In Telangana, it is cultivated in an area of 0.15 million hectares with a production of 0.25 million tonnes with average productivity of 1625 kg/ha [1].

Soybean is a major source of seed protein and oil content. Per 100 g, soybean oil has 16 g of saturated fat, 23 g of monounsaturated fat and 58 g of polyunsaturated fat. The major unsaturated fatty acids in soybean are alpha-linolenic acid (C-18:3), 7-10% & linoleic acid (C-18:2), 51%; and the mono-unsaturated, oleic acid (C-18:1), 23%. It also contains saturated fatty acids, stearic acid (C-18:0), 4% & palmitic acid, (C-16:0) 10% [2].

In the state of Telangana, soybean grown during Kharif season is challenged by several biotic and abiotic stresses. Among various factors hampering the realization of the actual yield potential of soybean, pre-harvest sprouting (PHS) is an important one that affects the yield and quality of seed, when grain maturity coincides with heavy and continuous rains. The phenomenon of germination of seeds in the pod, usually under wet conditions shortly before harvest, is termed pre-harvest sprouting (PHS). It is also termed vivipary [3]. Lack of adequate dormancy results in pre-harvest sprouting in the field under wet weather conditions [4]. Pre-harvest sprouting (PHS) has been recognized as one of the main factors that decrease the yield and quality of crops worldwide especially in wet harvest period [5].

Pre-harvest sprouting is an important detrimental factor in soybean production. As very few reports are available on this aspect, the present study was carried out to assess the genetic variation for PHS tolerance in soybean and to determine the relationship between pre-harvest sprouting with various plant, pod and seed characters, their direct and indirect effects on PHS, and to identify potential sources of PHS tolerance in the soybean germplasm.

2. MATERIALS AND METHODS

A field experiment was conducted to screen 65 diverse genotypes of soybean for pre-harvest sprouting during Kharif, 2019 at Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad District, Telangana State which is located at 77°88 East and 18°58 North at an elevation 404 m above mean sea level. The soil pH at the test location ranged from 7.5 – 8.0. The experiment was laid out in Randomized Complete Block Design (RCBD) with two replications. Each genotype is grown in 2 rows of 2 m length at a spacing of 30×10 cm. Recommended package of practices were followed to raise a healthy crop. Observations were recorded on ten randomly selected plants from each plot for the traits plant height (cm), number of branches per plant, number of clusters per plant, number of pods per plant, 100 seed weight (g), seed yield per plant (g), number of pods ruptured by sprouting seed per plant and percentage of pods ruptured by sprouting seed (PPR). Days to 50% flowering was recorded on whole plot basis. Observations on pod length (cm), pod diameter (cm) and pod wall thickness (mm) were recorded on one set of 10 pods from each replication. Each set of 10 pods comprised of 2 pods from each of the five randomly taken plants at R7 (beginning maturity) stage. Pod wall thickness was recorded using a screw gauge.

Data on rainfall and relative humidity (RH) of the area was recorded. The crop received rainfall of 300.9 mm in September and 123.4 mm in October-2019 with 21 and 7 rainy days respectively. Average relative humidity recorded 88.7% in September and 89.26% in October month. During the 2nd, 3rd and 4th week of October 116 mm of rainfall was recorded in seven rainy days. This period coincided with maturity period of almost all the test entries. The matured pods of each genotype which received rainfall during the maturity stage were thoroughly observed for sprouting of seed prior to harvesting. To determine the resistance to pre-harvest sprouting, the percentage of pods ruptured by sprouting seed (PPR) was measured and used as a measure of PHS tolerance in the genotypes. In each genotype number of ruptured pods by sprouting seed were counted for ten randomly selected plants and expressed in percentage by using following formula.

**Keywords:** Soybean; pre-harvest sprouting; variability; GCV; PCV; heritability; path coefficient analysis.
The data were analyzed for analysis of variance, genotypic and phenotypic coefficients of variation, heritability, genetic advance, genetic advance as per cent mean, correlation and path coefficient analysis using OPSTAT software [6].

3. RESULTS AND DISCUSSION

The analysis of variance indicated significant differences among genotypes except pod length, pod diameter, pod wall thickness (Table 1).

Among the genotypes under study NRC-119 (0%) recorded lowest percentage of pods ruptured by sprouting seed (PPR) followed by NRC-73 (0.2%) and ASB-09 (0.3%) whereas the genotype AMS-MB-5-19 (5.8%) exhibited the highest percentage of pods ruptured by sprouting seed (PPR) followed by VP-1165 (5.7%), Himso-1686 (4.9%) and PS-1556 (4.9%) Table 2. The above mentioned varieties also exhibited more pod wall thickness. Most of the genotypes with pubescence recorded varying degrees of PPR. The presence of hairs on the pod surface might have led to the retention of rainwater for a considerable period of time thereby accelerating the germination process of the physiologically matured seed as earlier reported by Bhuyani and Sharma [7]. Negative association of pod pubescence with pre-harvest sprouting in soybean was reported by Dougherty and Boerma [8]. The mean number of ruptured pods by sprouting seed per plant ranged from 0 (NRC-119) to 2.9 (VP-1165).

### Table 1. Mean squares for 12 characters in 65 soybean genotypes

| Character                          | Replication | Treatments | Error | CV (%) | CD | SE(m) |
|-----------------------------------|-------------|------------|-------|--------|----|-------|
| Days to 50% flowering             | 0.931       | 7.157**    | 0.525 | 1.801  | 1.450 | 0.512 |
| Plant height (cm)                  | 16.277      | 288.737*   | 65.464 | 12.004 | 16.202 | 5.721 |
| Number of branches per plant      | 0.623       | 7.053**    | 0.701 | 18.545 | 1.677 | 0.592 |
| Number of clusters per plant      | 24.992**    | 15.296**   | 1445  | 8.416  | 2.407 | 0.850 |
| Number of pods per plant          | 1.3         | 266.817**  | 10.3  | 6.377  | 6.426 | 2.269 |
| Pod length (cm)                   | 1.221**     | 1.6        | 0.101 | 7.305  | 0.635 | 0.224 |
| Pod diameter (cm)                 | 0.192*      | 0.109      | 0.03  | 6.706  | 0.454 | 0.122 |
| Pod wall thickness (mm)           | 0.001       | 0.004      | 0.002 | 13.202 | 0.087 | 0.031 |
| 100 seed weight (g)               | 0.136       | 4.236*     | 0.960 | 6.729  | 1.962 | 0.693 |
| Seed yield per plant (g)          | 1.035       | 17.372**   | 1.391 | 8.152  | 2.362 | 0.834 |
| Number of pods ruptured by sprouting seed per plant | 0.001 | 0.937** | 0.022 | 16.142 | 0.297 | 0.105 |
| Percentage of pods ruptured by sprouting seed (PPR) | 0.079 | 4.024** | 0.140 | 19.84  | 0.751 | 0.265 |

**CV** = Coefficient of variation, **CD** = Critical difference, **SE(m)** = Standard Error of the Mean; **1% level of significance**

### Table 2. List of genotypes with minimum and maximum percentage of pods ruptured by sprouting seed (PPR) and number of pods ruptured by sprouting seed per plant

| Name of the genotype | Percentage of pods ruptured by sprouting seed (PPR) | Name of the genotype | Percentage of pods ruptured by sprouting seed (PPR) | Number of pods ruptured by sprouting seed per plant |
|----------------------|-----------------------------------------------------|----------------------|-----------------------------------------------------|-------------------------------------------------|
| NRC-119              | 0.0                                                 | NRC-119              | 0.0                                                 | VP-1165                                         |
| NRC-73               | 0.2                                                 | NRC-73               | 0.1                                                 | VP-1165                                         |
| ASB-09               | 0.3                                                 | ASB-09               | 0.2                                                 | VP-1165                                         |
| KDS-780              | 0.4                                                 | KDS-869              | 0.2                                                 | VP-1165                                         |
| KDS-869              | 0.4                                                 | KDS-869              | 0.2                                                 | VP-1165                                         |
| NRC-2007-A-23        | 4.5                                                 | DSB-25               | 2.2                                                 | VP-1165                                         |
| PS-1556              | 4.9                                                 | NRC-2007-A-3-1       | 2.2                                                 | VP-1165                                         |
| HIMSO-1686           | 4.9                                                 | NRC-2007-1-1         | 2.2                                                 | VP-1165                                         |
| VP-1165              | 5.7                                                 | NRC-2007-1-3-1       | 2.2                                                 | VP-1165                                         |
| AMS-MB-5-19          | 5.8                                                 | VP-1165              | 2.2                                                 | VP-1165                                         |
Table 3. Grand mean, range, genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability ($H^2$), genetic advance (GA) and genetic advance as percent of mean (GAM) for 12 different characters in 65 soybean genotypes

| Character                        | Grand mean | Range     | GCV (%) | PCV (%) | $H^2$ (%) | GA (%) | GAM   |
|----------------------------------|-----------|-----------|---------|---------|-----------|--------|-------|
| Days to 50% flowering            | 40.2      | 36 - 43.5 | 4.527   | 4.872   | 86.343    | 3.486  | 8.666 |
| Plant height (cm)                | 67.4      | 34.5 - 94 | 15.676  | 19.745  | 63.036    | 17.281 | 25.639|
| Number of branches per plant     | 4.5       | 2.5 - 11  | 35.022  | 39.629  | 78.101    | 2.879  | 63.758|
| Number of clusters per plant     | 14.2      | 8.5 - 20  | 18.423  | 20.254  | 82.733    | 4.931  | 34.519|
| Number of pods per plant         | 50.3      | 28 - 80.5 | 22.501  | 23.387  | 92.566    | 22.446 | 44.597|
| Pod length (cm)                  | 4.3       | 3.7 - 5.45| 3.977   | 8.318   | 22.863    | 0.170  | 3.918 |
| Pod diameter (cm)                | 2.5       | 2.2 - 3.25| 7.756   | 10.253  | 57.221    | 0.310  | 12.086|
| Pod wall thickness (mm)           | 0.32      | 0.2 - 0.43| 10.471  | 16.850  | 38.613    | 0.044  | 13.403|
| 100 seed weight (g)              | 14.5      | 11.6 - 17.75| 8.791   | 11.070  | 63.057    | 2.094  | 14.380|
| Seed yield per plant (g)          | 14.4      | 8.8 - 21.4| 19.538  | 21.171  | 85.173    | 5.374  | 37.146|
| Number of pods ruptured by sprouting seed per plant | 0.9 | 0 - 2.9 | 73.705 | 75.452 | 95.423 | 1.361 | 148.318 |
| Percentage of pods ruptured by sprouting seed (PPR) | 1.8 | 0 - 5.85 | 73.755 | 76.377 | 93.253 | 2.772 | 146.721 |
Table 4. Phenotypic (rp) and genotypic (rg)) correlation coefficient for percentage of pods ruptured by sprouting seed (PPR) and various plant, pod, seed parameters for 12 different characters in 65 soybean genotypes

| Characters | Days to 50% flowering | Plant height | Number of branches per plant | Number of clusters per plant | Number of Pods per plant | Pod length | Pod diameter | Pod wall thickness | 100 seed weight | Seed yield per plant | PR | PPR |
|------------|------------------------|--------------|------------------------------|------------------------------|--------------------------|------------|-------------|-------------------|----------------|----------------------|----|-----|
| Days to 50% flowering | rp 1 | 0.321** | 0.104 | 0.168 | 0.222* | 0.234** | -0.054 | 0.030 | -0.083 | 0.173* | -0.073 | -0.133 |
| flowering | rg 1 | 0.476** | 0.153 | 0.207* | 0.249** | 0.543** | -0.128 | 0.152 | -0.164 | 0.204 | 0.08 | -0.147 |
| Plant height | rp 1 | -0.090 | 0.031 | 0.091 | 0.137 | 0.137 | -0.073 | -0.109 | -0.178* | -0.025 | 0.074 | -0.005 |
| rg 1 | -0.197* | 0.037 | 0.088 | 0.240** | -0.262** | -0.300** | -0.243** | 0.077 | 0.057 | -0.050 |
| Number of branches per plant | rp 1 | 0.205* | 0.187* | -0.230** | -0.069 | -0.087 | -0.112 | 0.178* | 0.091 | 0.083 |
| rg 1 | 0.189* | 0.013 | 0.013 | -0.052 | -0.240** | 0.539** | -0.001 | -0.177* |
| Number of clusters per plant | rp 1 | 0.758** | 0.178* | 0.013 | -0.052 | -0.240** | 0.539** | -0.001 | -0.177* |
| rg 1 | 0.844** | 0.427** | -0.018 | -0.161 | -0.305** | 0.834 | 0.004 | -0.197* |
| Number of pods per plant | rp 1 | 0.139 | -0.011 | -0.037 | -0.037 | 0.769** | 0.069 | -0.204* |
| rg 1 | 0.294** | -0.027 | -0.056 | -0.036 | 0.848** | 0.068 | -0.196* |
| Pod length | rp 1 | 0.036 | -0.072 | 0.024 | 0.038 | -0.032 | -0.058 |
| rg 1 | -0.309** | -0.182* | 0.243** | 0.160 | -0.071 | -0.141 |
| Pod diameter | rp 1 | 0.050 | 0.350** | 0.083 | -0.067 | -0.069 |
| rg 1 | -0.114 | 0.450** | 0.142 | -0.070 | -0.069 |
| Pod wall thickness | rp 1 | 0.141 | 0.031 | -0.206* | -0.214* | 0.016 | -0.017 | -0.232** | -0.242** |
| 100 seed weight | rp 1 | 0.079 | -0.069 | -0.045 |
| weight | rg 1 | 0.082 | -0.074 | -0.046 |
| Seed yield | rp 1 | -0.056 | -0.148 |
| per plant | rg 1 | 0.090 | -0.132 |
| PR | rp 1 | 0.936** |
| rg 1 | 0.944** |

* Significant at 5 per cent level; ** Significant at 1 per cent level; PR = number of pods ruptured by sprouting seed per plant; PPR = Percentage of pods ruptured by sprouting seed
Table 5. Direct and indirect effects of various plant, pod, seed parameters under study on percentage of pods ruptured by sprouting seed (PPR) in 65 soybean genotypes

| Days to 50% flowering | Plant height | Number of branches per plant | Number of clusters per plant | Number of Pods per plant | Pod length | Pod diameter | Pod wall thickness | 100 seed weight | Seed yield/ plant | PR (PPR) |
|-----------------------|-------------|-------------------------------|-----------------------------|--------------------------|-----------|-------------|------------------|----------------|-----------------|----------|
| Days to 50% flowering | rp 0.0094   | -0.0156                       | 0.0035                      | 0.0119                   | -0.0751   | 0.0028      | -0.0009          | -0.0026        | 0.0018          | -0.0694  |
| flowering             | rp -0.0467  | -0.0676                       | 0.0058                      | -0.0524                  | -0.0325   | 0.1022      | -0.0009          | -0.0087        | 0.0286          | -0.0752  |
| Plant height          | rp 0.0030   | -0.0486                       | -0.0030                     | 0.0022                   | -0.0307   | 0.0016      | 0.0014           | 0.0005         | 0.0002          | 0.0709   |
| branches per plant    | rg -0.0222  | -0.1420                       | -0.0075                     | -0.0094                  | -0.0114   | 0.0542      | -0.0192          | 0.0017         | 0.0424          | 0.0036   |
| branches per plant    | rg -0.0071  | 0.0280                        | 0.0381                      | -0.0480                  | -0.0244   | -0.0433     | -0.0050          | 0.0050         | 0.0214          | 0.0763   |
| Number of clusters per plant | rg -0.0071 | 0.0280 | 0.0381 | -0.0480 | -0.0244 | -0.0433 | -0.0050 | 0.0050 | 0.0214 | 0.0763 |
| Number of pods per plant | rg -0.0071 | 0.0280 | 0.0381 | -0.0480 | -0.0244 | -0.0433 | -0.0050 | 0.0050 | 0.0214 | 0.0763 |
| Pod length            | rp 0.0021   | -0.0044                       | 0.0060                      | 0.0540                   | -0.3383   | 0.0016      | 0.0002           | -0.0111        | 0.0081          | 0.0660   |
| Pod diameter          | rg -0.0116  | -0.0124                       | 0.0071                      | -0.2140                  | -0.1308   | 0.0553      | -0.0020          | 0.0032         | 0.0663          | -0.0373  |
| Pod wall thickness    | rp 0.0022   | -0.0066                       | -0.0037                     | 0.0126                   | -0.0470   | 0.0121      | -0.0007          | 0.0023         | 0.0004          | -0.0302  |
| 100 seed weight       | rg -0.0254  | -0.0341                       | -0.0088                     | -0.1083                  | -0.0384   | 0.1882      | -0.0226          | 0.0104         | -0.0423         | -0.0666  |
| weight                | rg -0.0057  | 0.0030                        | 0.0030                      | 0.0009                   | 0.0037    | 0.0004      | -0.0205          | -0.0016        | 0.0110          | 0.0637   |
| Seed yield/ plant     | rp 0.0065   | 0.0372                        | 0.0026                      | 0.0045                   | 0.0035    | -0.0581     | 0.7333           | 0.0065         | -0.0797         | 0.0663   |
| PR                    | rg -0.0009  | 0.0050                        | 0.0003                      | 0.0002                   | 0.0020    | -0.0007     | 0.0017           | 0.0316         | 0.0048          | -0.0675  |
| Phenotypic residual effect = 0.04298; Genotypic residual effect = 0.03370; rp represents Phenotypic correlation coefficient; rg represents Genotypic correlation coefficient. Bold values are direct effects; PR = number of pods ruptured by sprouting seed per plant; PPR = Percentage of pods ruptured by sprouting seed.
Estimates of the genotypic and phenotypic coefficient of variation, broad-sense heritability and genetic advance for PPR and other plant, pod and seed characters are given in Table 3. In all cases, the values of PCV were higher than GCV, indicating the influence of the environment on the expression of such traits. The same was reported in research findings of Baraskar et al. [9]; Ravindra Kumar et al. [10]; Besufikad [11]; Deepak et al. [12]. The genotypic coefficient of variance ranged from 3.977 (pod length) to 73.755 (Percentage of pods ruptured by sprouting seed (PPR). High PCV and GCV was found for PPR, number of ruptured pods by sprouting seed per plant, number of branches per plant, number of pods per plant, indicating presence of sufficient inherent genetic variance for which selection can be effective. Similar results were obtained by Amrit et al. [13] for PHS in mungbean. Similar results for pods per plant was also reported by Aditya et al. [14]; Baraskar et al. [9]; Ravindra Kumar et al. [10]. Deepak et al. [12]; Nidhi et al. [15] for pods/plant and branches/plant. Days to 50% flowering and pod length recorded low GCV and PCV suggesting to go for source of high variability for these traits to improve. Baraskar et al. [9] and Deepak et al. [12] also reported similar results for days to 50% flowering and Soleh et al. [16] for pod length.

Heritability was found to be highest for number of ruptured pods by sprouting seed per plant (95.423%) followed by PPR (93.253%), number of pods per plant (92.566%), Days to 50% flowering (86.343%), seed yield per plant (85.173%), number of clusters per plant (82.733%), number of branches per plant (78.101%), 100-seed weight (63.057%) and plant height (63.036%). High values of heritability in broad sense for these characters indicates that they are less influenced by environment. High heritability for PHS was also reported by Amrit et al. [13] in mungbean. Faisal et al. [17] reported similar results for days to 50% flowering, 100-seed weight, grain yield per plant and plant height. High values of heritability for days to 50% flowering, number of branches per plant and 100-seed weight are also reported by Aditya et al. [14].

Heritability estimates along with genetic advance estimates are useful in predicting the gain under selection than heritability estimates alone. Estimates of genetic advance were high for pods/plant and moderate for plant height. These results are in accordance with Aditya et al. [14]; Ravindra Kumar et al. [10]. Expected genetic advance as per cent mean determines the mode of gene action and thereby selection of appropriate breeding method. The genetic advance as percentage of mean was recorded for number of ruptured pods by sprouting seed per plant. The higher genetic advance as percentage of mean for PHS was also reported by Amrit et al. [11] in mungbean. High heritability and high genetic advance as percentage of mean for number of ruptured pods by sprouting seed per plant and Percentage of pods ruptured by sprouting seed (PPR) indicates the presence of additive gene action for these traits and suggests reliable soybean improvement through selection for these traits. High heritability and high genetic advance as percent mean for PHS was reported by Amrit et al. [11] in mungbean. Deresse [18] also reported similar results for plant height. Similar results for number of pods per plant, number of clusters per plant, plant height, 100-seed weight, number of branches per plant and days to 50% flowering were also obtained by Neelima et al. [19]. Number of pods per plant recorded high values of heritability and genetic advance with high GCV and PCV. Similar results were obtained by Malek et al. [20].

The genotypic and phenotypic correlations for percentage of pods ruptured by sprouting seed (PPR) and various plant, pod, seed parameters are presented in Table 4. In general, genotypic correlations were of higher magnitude than the corresponding phenotypic values which indicates that though there is strong inherent association between characters studied, its expression is lessened due to influence of environment and considering the importance of phenotypic correlation it was discussed in the results. Percentage of pods ruptured by sprouting seed (PPR) exhibited significant negative phenotypic correlation with pod wall thickness (−0.214), number of pods per plant (−0.204), number of clusters/plant (−0.177). Similar non-significant association was reported with number of pods per plant, number of clusters per plant by Sarfraz et al. (2014). This character had negative phenotypic association with almost all the characters under study except number of branches per plant (0.083) and number of pods
raptured by sprouting seed per plant (0.936). Similar association with pod diameter and plant height was obtained by Sharma et al. [3] in soybean. A negative association of percentage of pods ruptured by sprouting seed (PPR) with seed yield per plant indicates that the percentage of seed sprouted is directly related to percentage of seed damage and yield loss. Identification of pre-harvest sprouting resistance is, therefore, important in view of its affect on seed yield in high rainfall area as earlier reported by Sharama et al. [21]. Significant negative association of number of branches per plant with PHS was reported in mungbean by Amrit et al. [13]. Number of pods ruptured by sprouting seed per plant reported significant negative phenotypic correlation with pod wall thickness (-0.206). This character also exhibited negative correlation with days to 50% flowering (-0.073), number of clusters per plant (-0.001), number of pod length (-0.032), pod diameter (-0.067) and 100-seed weight (-0.069). The significant negative correlation of pod wall thickness with PPR and number of pods ruptured by sprouting seed per plant may be due to stronger barrier posed by a thicker pod wall to water leading to reduced incidence of PHS as reported by Sharma et al. [3]. A negative association between pod wall thickness and seed germination % in pods has, however, been reported earlier in soybean by Tekrony et al. [22] and in mungbean by William [23].

Path coefficient analysis allows separation of the direct effect and their indirect effects through other attributes by partitioning the correlations Wright [24]. Hence, the path coefficient analysis was undertaken to know the direct and indirect effects of various characters on PHS tolerance in soybean. Path coefficient analysis showed that highest positive direct effect on PPR was exhibited by number of pods ruptured by sprouting seed per plant (0.9548) (Table 5). Direct positive effect on PPR was also exhibited by days to 50% flowering (0.0094), number of branches per plant (0.0343), number of clusters per plant (0.0713), pod length (0.0121), 100-seed weight (0.0316) and seed yield per plant (0.0105). Sarfraz et al. (2014) reported direct positive effect with pod length in mungbean. Sharma et al. [3] find similar results with number of clusters per plant and 100-seed weight in soybean. Highest negative direct effect on PPR was exhibited by number of pods per plant (-0.3383) followed by Plant height (-0.0486) and pod wall thickness (-0.0323). Similar results were obtained by Sharma et al. [3] in soybean with number of pods per plant and plant height, in mungbean with number of pods per plant by Sarfraz et al. (2014). Indirect positive influence of number of pods ruptured by sprouting seed/plant on PPR was observed through number of branches per plant (0.0031), pod diameter (0.0013), pod wall thickness (0.0066) and seed yield per plant (0.0005). Days to 50% flowering has negative indirect effect via plant height (-0.0156), number of pods per plant (-0.0751), pod wall thickness (-0.0009), 100-seed weight (-0.0026) and number of pods ruptured by sprouting seed per plant (-0.0694). Pod wall thickness has negative influence through number of branches per plant (-0.0018), number of clusters per plant (-0.0037), pod length (-0.0008), pod diameter (-0.0010) and number of pods ruptured by sprouting seed per plant. Positive influence of number of pods ruptured by sprouting seed per plant on PPR was recorded through number of branches per plant (0.0031), pod diameter (0.0013), pod wall thickness (0.0066) and seed yield per plant (0.0005) but the values were very low. It had highest negative influence through number of pods per plant (-0.0234).

4. CONCLUSION

In this investigation, percentage of pods ruptured by sprouting seed (PPR) was measured and used as a measure of PHS tolerance in the genotypes. High PCV and GCV was found for percentage of pods ruptured by sprouting seed (PPR) indicating presence of sufficient inherent genetic variance for this trait, over which selection can be effective. Association studies revealed pod wall thickness, number of pods per plant and number of clusters per plant are positively associated with PHS tolerance. A negative association of PPR with seed yield per plant indicates the importance of identification of pre-harvest sprouting resistance in view of its affect on seed yield reduction. In this study, soybean genotypes viz., NRC-119, NRC-73, ASB-09, KDS-780 and KDS-869 etc., were identified with relatively lower incidence of PHS. Multi-location and multi-season evaluation of these genotypes, however, is required before using these genotypes in breeding programmes as PHS is a complex trait and is controlled by many genes showing significant interaction with the environment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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