RESEARCH ARTICLE Legume Research- An International Journal, Volume 44 Issue 5: 568-573 (May 2021)

Pod Positions on the Plant Associated with Pod Shattering Resistance in Soybean Genotypes

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ABSTRACT

Background: One of the major constraints of soybean production in Indonesia is pod shattering which occurs after soybean pod maturity. This study aimed to identify the pod shattering resistance of different pod positions in the plant stem.

Methods: Sixteen genotypes were evaluated in the field research during the dry season 2019. The experiment was laid out in a randomized block design with three replicates. Ten sample plants were randomly taken after R8 phase. Plant was divided into three parts, *i.e.* upper part, middle part and lower part. The shattering evaluation was done using the oven-dry method in the laboratory. The observation on the number of shattered pods was measured for each part of plant stem.

Result: Pod shattering was different among the pod positions as well as among genotypes. One genotype was categorized as resistant, eight genotypes were moderate, six genotypes were susceptible and one genotype was highly susceptible. The highest percentage of the shattered pods was in the lower part of the plant stem, followed by the middle and upper part, respectively. The resistant genotypes showed the shattered pods mostly in the lower part of the stem, the moderate genotypes showed the shattered pods mostly in the lower and middle part of the stem and the susceptible genotypes shattered in all part of the stem.

Key words: Correlation, Pod morphology, Pod-shatter determinant, Seed characters, Shattering pattern.

INTRODUCTION

In soybean plant, pods are agronomic character which plays a direct role in determining the seed yield. On the other hand, pod shattering becomes a problem in the soybean production centers in the world since it caused a decrease in soybean productivity and seed quality (Shivankar *et al.* 2001). The importance of the pod shattering in soybean can be seen from the significant amount of the yield losses (Philbrook and Oplinger, 1989; Tukamuhabwa *et al.* 2002; Yue *et al.* 2006). The range of yield loss in the susceptible cultivar reached 50 to 100% in the dry condition (Bhor *et al.* 2014). The pod shattering in Indonesia is crucial, related to the season of the soybean cultivation. The soybeans are mostly cultivated during the dry season. Thus, the seed filling and maturation were in the peak of the dry season which potential to trigger the shattering.

The pod formation in soybean is beginning with the floral initiation in the nodes of the plant which grow continually until the upper part of the plant (Heitholt *et al.* 1986). It indicates differences in the level of maturity of the pods in a plant as a result of differences in the time of floral formation which also resulted in the differences in the pod shattering. Pod shattering can be defined as the process of the opening of the mature pods started from the tip of the ventral suture (Bara *et al.* 2013; Krisnawati and Adie, 2017a). In rapeseed, shattering involves the detachment of the pod valves, including the seed, from the replum (Rameeh, 2013).

The pod shattering attribute is a complex character determined by genetics as well as environmental factors. From the genetic approach, Mohammed *et al.* (2014) reported that inheritance of resistance to pod shattering in soybean was under the influence of either duplicate recessive or dominant and recessive epistasis depending on the parental genotypes used in the cross. In rice bean, Jadhav *et al.* (2001) reported that pod shattering had high genetic advance, indicates that it was controlled by additive gene action. Based on the research by Umar *et al.* (2017) in the combining ability estimates for pod shattering, it was suggested that the selection for pod shattering could be done in the later generation. Krisnawati *et al.* (2019a) have successfully selected a total of 104 very resistant lines in the 591 F_5 segregating population of soybean derived from crosses of the resistant parent. A screening for pod shattering in the mutant populations of greengram obtained nine tolerant mutants in the M_3 generation (Vairam *et al.* 2017). In the molecular approach, Thakare *et al.* (2017) have found two markers that could be utilized in the marker assisted for pod shattering resistance.

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How to cite this article: Krisnawati, A., Soegianto, A., Waluyo, B., Adie, M.M., Mejaya, M.J. and Kuswanto (2021). Pod Positions on the Plant Associated with Pod Shattering Resistance in Soybean Genotypes. Legume Research. 44(5): 568-573. DOI: 10.18805/LR-588.

Submitted: 17-09-2020 **Accepted:** 22-11-2020 **Online:** 26-01-2021

So far, the study on the effect of the soybean pod positions on the stem to pod shattering resistance is still limited. Furthermore, the information regarding the shattering patterns of soybean cultivars with different resistance on different pod position is also not available yet. The result obtained from this study provides preliminary information for further study related to the pattern of shattering in the different pod positions on the soybean stem. This study aimed to identify the pod shattering resistance of soybean in the different pod positions in the plant stem.

MATERIALS AND METHODS

Materials

The research materials were fourteen soybean genotypes and two check cultivars. The fourteen genotypes were promising lines (F_8) derived from a selection of four crosses population. The check cultivars were Detap 1 (shattering-resistant cultivar) and Dega 1 (shattering-susceptible cultivar).

Field experiment

Sixteen genotypes were planted in the Muneng Research Station (Probolinggo, East Java, Indonesia) of the Indonesian Legume and Tuber Crops Research Institute (ILETRI), during the dry season of 2019. The field research was conducted in lowland after rice cultivation with soil tillage. The field experiment was arranged in a randomized block design with four replications. The plot size for each genotype was 2 m × 4.5 m with planting distance of 40 cm × 15 cm. Fertilizer was applied at the rate of 50 kg/ha Urea, 100 kg/ha SP36 and 75 kg/ha KCl in the sowing time. Management of weeds, pests and diseases was done intensively.

Pod shattering evaluation in the laboratory

Ten randomly plants were taken from each genotype when plants reached full maturity (R_8). The sample plants were dried at room temperature for three days. Each sample plant was divided into three parts, *i.e.* upper part, middle part and lower part. Twenty sample pods for evaluation of shattering resistance were randomly taken from ten plants of each genotype. The shattering evaluation was based on the oven-dry method (Krisnawati and Adie, 2017b), *i.e*. the sample pods were dried at 30°C for three days and then elevated to 40°C (one day), 50°C (one day) and 60°C (one day). The observation on the number of shattered pods was made for each part after being subjected to each oven temperature. The shattering percentage was calculated as the number of shattered pods per total number of pods expressed as a percentage. The classification of shattering resistance was according to the AVRDC (1979), as follows: highly resistant (0% shattering), resistant (1-10% shattering), moderately resistant (11-25%), susceptible (26-50%) and highly susceptible (> 50% shattering).

Observation and data analysis

Observations made on the total shattering percentage of all parts, shattering percentage of each part, plant height (cm), pods characters (pod length, pod width, pod height and pod thickness), seed characters (seed length, seed width and seed thickness), pod wall weight to pod weight ratio, seed weight to pod weight ratio and weight of individual seed. The measurement of pod and seed characters were based on Bara *et al.* (2013). The data were subjected to correlation analysis (Singh and Chaudhary, 1979) to observe the determinant factors of pod shattering resistance.

RESULTS AND DISCUSSION

Pod shattering resistance

The average shattering for sixteen soybean genotypes are presented in Table 1. The shattered pods of all genotypes were mostly started at 50°C with an average of 9% and

Table 1: Pod shattering of 16 soybean genotypes.

No	Genotype	Pod shattering (%)				Category of resistance at 60°C
		30°C	40°C	50°C	60°C	
1	Anj/G100H-6	0	0	2	17	Moderately resistant
2	Anj/G100H-14	0	0	5	35	Susceptible
3	Anj/G100H-16	0	0	0	7	Resistant
4	Anj/G100H-21	0	0	0	23	Moderately resistant
5	Anj/G100H-24	0	0	0	12	Moderately resistant
6	Anj/G100H-28	0	0	3	33	Susceptible
7	Anj/G100H-44	0	0	0	28	Susceptible
8	Anj/IAC100-19	0	0	2	35	Susceptible
9	Anj/Rjbs-304	0	0	27	47	Susceptible
10	Anj/Rjbs-305	0	0	3	13	Moderately resistant
11	Anj/Rjbs-306	0	0	0	13	Moderately resistant
12	Anj/Rjbs-309	0	0	3	37	Susceptible
13	Anj/ Rjbs-311	0	0	2	17	Moderately resistant
14	Grbg/Anj-2	0	0	0	17	Moderately resistant
15	Dega 1	0	0	100	100	Highly Susceptible
16	Detap 1	0	0	0	13	Moderately resistant
	Average	0	0	9	28	

then the average of shattering was increased up to 28% at 60°C. The shattering variation which started at 50°C of the oven-dry method was also reported in the shattering evaluation of the F_6 soybean population (Krisnawati *et al.* 2019b).

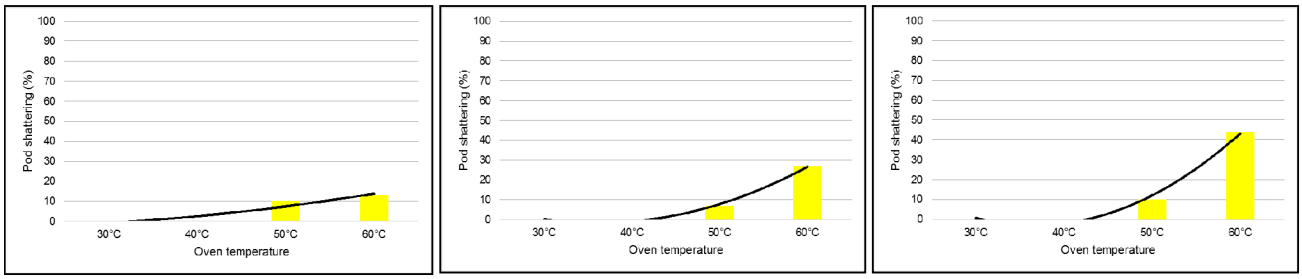
Perusal of Table 1 showed that there were two resistant genotypes, seven moderately resistant genotypes, six susceptible genotypes and one highly susceptible genotype. The degree of resistance ranged from resistant to highly susceptible and no any genotype found as highly resistant. Similarly, the previous studies did not find a highly resistant genotypes or with zero shattering (Adeyeye *et al.* 2014; Antwi-Boasiako, 2017). However, other studies have successfully obtained very resistant genotypes (Romkaew and Umezaki, 2006; Adie and Krisnawati, 2016). The varying results on the shattering resistance in those studies could be caused by the difference in the genetic background of the genotypes used and the quantifying method for shattering resistance (Bhor *et al.* 2014; Gan *et al.* 2008). The shatter-resistant genotypes identified from the present study could be used for the improvement of the plant to minimize the yield losses in soybean.

Shattering at different pod positions

The pod shattering on three pod positions on the stem shows different patterns (Fig 1). The highest percentage of the shattered pods was in the lower part of the stem (52%) followed by the middle part (32%) and the upper part (15%), respectively. Thus, pods at the lower part of the stem contributed more than 50% of shattering in a soybean plant. This result is in line with the results obtained by Krisnawati and Adie (2017a) using an ambient temperature method. According to Romkaew *et al.* (2007), the differences in the shattering resistance was due to the moisture content of the pods.

Summarizing the pod shattering pattern of three pod positions (Fig 1), it appears that the pod shattering pattern of pod position in the upper part shows a rather flat curve. Meanwhile, the pod shattering pattern of pod position in the middle part shows a curve with a slightly raised edge. The pod shattering pattern of pod position in the lower part shows a curve with a raising edge.

The patterns of pod shattering for each part position of the pods for each genotype are presented in Fig 2. Each soybean genotype shows different pod shattering patterns, either due to differences in shattering among pod positions



(a) (b) (c)

Fig 1: The shattering pattern for (A) upper part, (B) middle part and (C) lower part of the soybean stem.

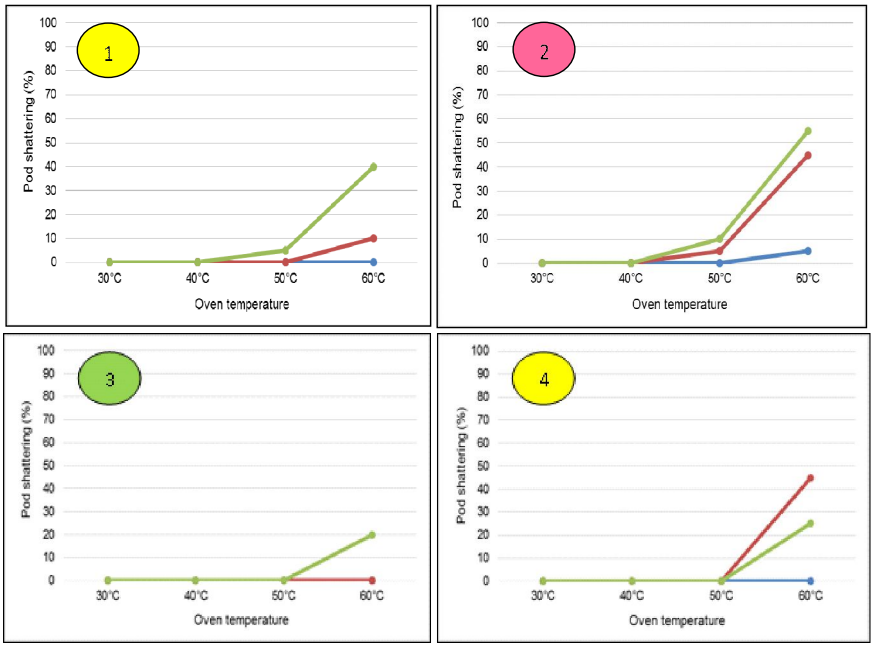


Fig 2: Continue...

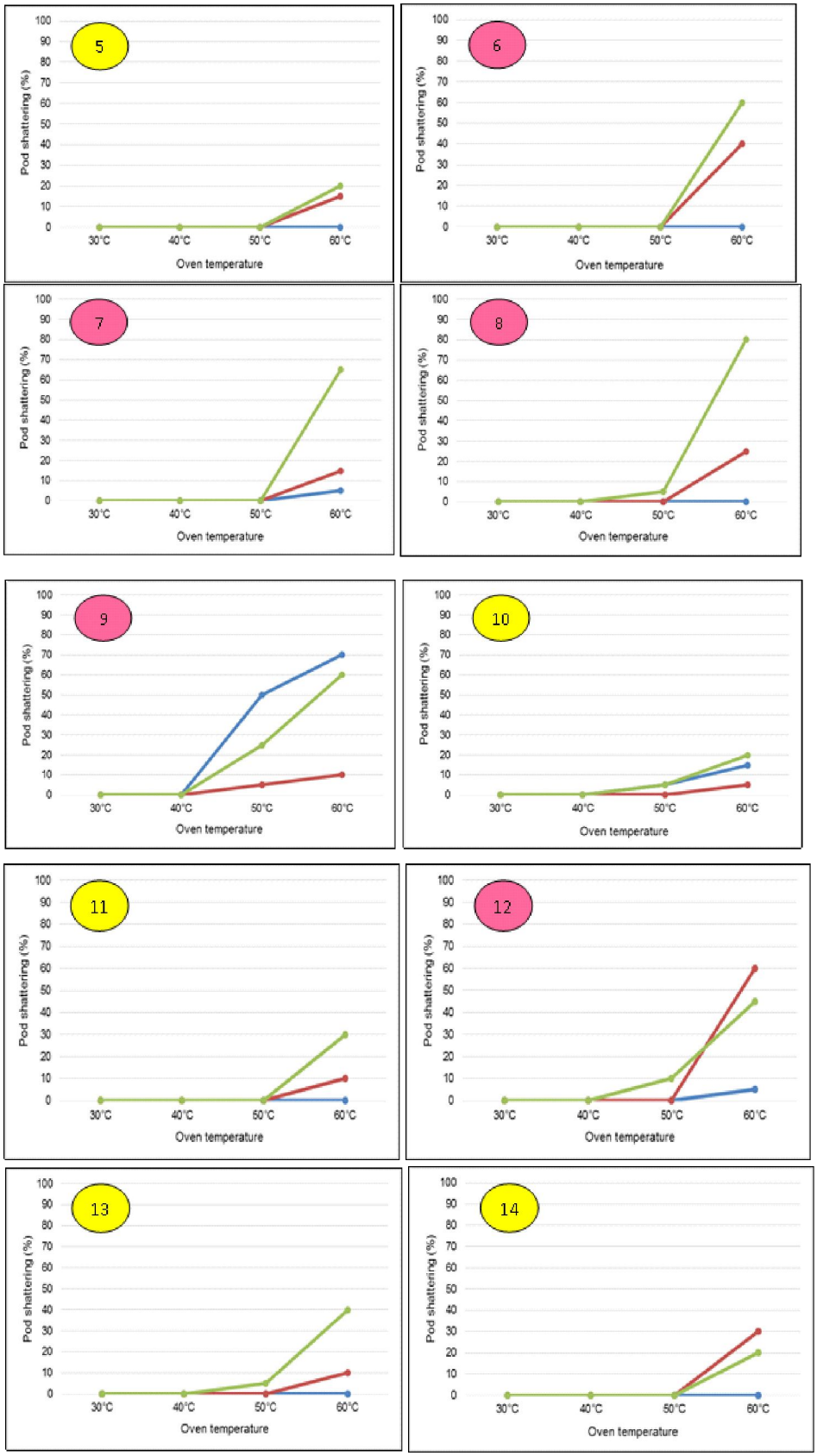


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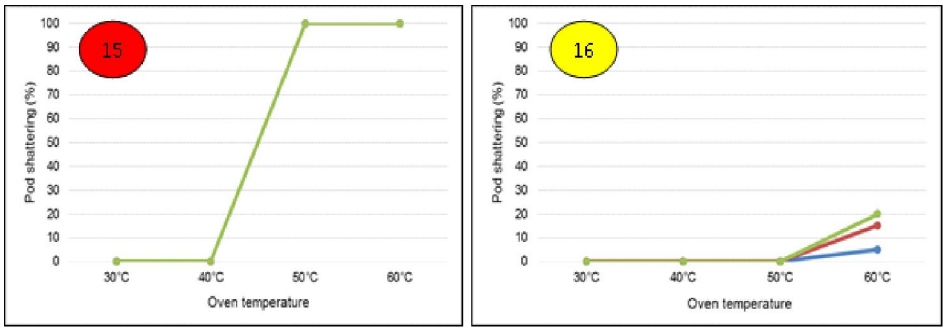


Fig 2: The pod shattering pattern of the different pod positions in the stem for each soybean genotype.

The number in the circle 1-16 represent the genotypes. The color background of the circle represents the degrees of resistance from each genotype: = resistant, = moderately resistant, = susceptible, = highly susceptible.

The lines in each figure represents the pod shattering percentage of each pod position in the stem: = lower part of the stem, = middle part of the stem, = upper part of the stem.

or due to the shattering resistance. The pod shattering of resistant genotype was started at 60°C and the shattered pods were mostly derived from the lower part of the stem. The group of moderate genotypes showed the shattered pods were mostly derived from the lower and middle parts of the stem. However, the percentage of shattering in the middle part was lower than those of the susceptible genotypes. The groups of susceptible genotypes showed the shattered pods derived from the lower, middle and upper parts of the stem. The susceptible genotypes showed a high percentage of shattering at the lower as well as middle parts of the stem and few shattered pods at the upper part of the stem. The highly susceptible genotype showed shattered pods in all parts of the stem.

The pods at the lower part of the stem aged older than the pods at the middle- and upper-part positions. According to the previous study, the flowering of cultivated and wild-type plants proceeded from the basal order racemes to the upper order racemes (Saitoh, *et al.* 1998). In mungbean, it was reported that the indeterminate flowering habit leads to a spread of flowering and pod maturity on a single plant over the entire reproductive phase. Consequently, pods that develop at the earliest flower may shatter prior to 100% pod maturity (Vairam *et al*. 2017).

Determinant factor for pod shattering resistance

The determinant factors for pod shattering resistance were investigated through the characters of pod morphology, seed morphology, plant height, pod weight and seed weight. The mean data of pod shattering and plant characters is presented in Table 2. All the plant characters, except the plant height and weight of individual seed, show no significant correlation with pod shattering at all pod positions (Table 3). The plant height showed a significant negative correlation with the pod shattering in all three parts position of the pods in the stem, *i.e*. r = -0.589** (upper part), r = -641** (middle part) and r = -0.505** (lower part). This shows that a shorter plant tended to have a higher percentage of pod shattering compared to the higher plant, especially if associated with the position of the pods.

Table 2: Mean data of pod shattering and plant characters at three different pod positions.

Characters	Mean value at three pod position on the stem		
	Upper	Middle	Lower
Pod shattering (%)	13	27	44
Plant height (cm)	14.54	14.55	14.10
Pod length (mm)	40.81	37.70	26.53
Pod width (mm)	14.48	14.33	9.10
Pod height (mm)	8.58	8.50	6.22
Pod thickness (mm)	5.73	5.49	3.83
Seed length (mm)	7.34	7.27	4.94
Seed width (mm)	8.02	8.01	4.21
Seed thickness (mm)	4.91	4.91	3.33
Pod wall weight to pod weight ratio	0.31	0.32	0.21
Seed weight to pod weight ratio	0.69	0.68	0.48
Weight of individual seed (g)	0.15	0.15	0.11

Table 3: Correlation between pod shattering at three different pod positions with plant characters.

Plant character	Pod shattering at 60°C		
	Upper	Middle	Lower
Plant height (cm)	-0.589**	-0.641**	-0.505*
Pod length (mm)	-0.028^{ns}	-0.249^{ns}	-0.214^{ns}
Pod width (mm)	-0.384^{ns}	0.095^{ns}	-0.329^{ns}
Pod height (mm)	-0.095^{ns}	0.191^{ns}	-0.364^{ns}
Pod thickness (mm)	-0.239^{ns}	0.004^{ns}	-0.212^{ns}
Seed length (mm)	-0.246^{ns}	0.082^{ns}	-0.211^{ns}
Seed width (mm)	-0.020^{ns}	-0.169^{ns}	-0.227^{ns}
Seed thickness (mm)	-0.453^{ns}	0.176^{ns}	-0.194^{ns}
Pod wall weight to pod weight ratio	0.404^{ns}	0.362^{ns}	-0.198^{ns}
Seed weight to pod weight ratio	-0.404^{ns}	-0.362^{ns}	-0.216^{ns}
Weight of individual seed (g)	-0.193^{ns}	0.467*	-0.138^{ns}

* = Significant at 5% probability level (P < 0.05), ** = Significant at 1% probability level (P < 0.01), ns = not significant.

The pod shattering from the middle part of the stem showed a significant positive correlation with the weight of the individual seed (r = 0.467*). This indicates that the heavier individual seeds will increase the percentage of pod shattering. Related to the seed characters, Kataliko *et al.* (2019) reported an increase in resistance to pod shattering towards a reduced number of seeds within a pod. In the present study, we use the detached sample pods from each part of pod positions in the stem. However, in the field, soybean pods will remain attached to the stem, hence a further study is needed to get closer to the simulation of the screening for shattering resistance by using the undetached pods.

CONCLUSION

The pod shattering varied among pod positions and among soybean genotypes. The pods at the lower part of the stem have a higher percentage of shattering compared to those of the middle and upper part of the stem. The resistant genotypes showed the shattered pods mostly in the lower part of the stem, the moderate genotypes showed the shattered pods mostly in the lower and middle part of the stem and the susceptible genotypes shattered in all parts of the stem.

REFERENCES

Adeyeye, A.S, Togun, A.O., Akanbi, W.B., Adepoju, I.O. and Ibirinde, D.O. (2014). Pod shattering of different soybean varieties, [*Glycine max* (L.) Merrill], as affected by some growth and yield parameters. International Journal of Agricultural Policy and Research. 2: 10-15.

Adie, M.M. and Krisnawati, A. (2016). Identification of soybean resistance to pod shattering in tropical agro-ecosystem. Transactions of Persatuan Genetic Malaysia. 3: 17-22.

Antwi-Boasiako, A. (2017). Screening of soybean [*Glycine max* (L.) Merrill] genotypes for resistance to lodging and pod shattering. International Journal of Agronomy and Agricultural Research. 10: 1-8.

AVRDC (Asian Vegetable Research and Development Centre). (1979). Soybean Report. Shanhwa, Taiwan, Republic of China.

Bara, N., Khare, D. and Srivastava, A.N. (2013). Studies on the factors affecting pod shattering in soybean. Indian Journal of Genetics and Plant Breeding. 73: 270-277.

Bhor, T.J., Chimote, V.P. and Deshmukh, M.P. (2014). Inheritance of pod shattering in soybean [*Glycine max* (L.) Merrill]. Electronic Journal of Plant Breeding. 5: 671-676.

Gan Y., Malhi S.S., Brandt S.A. and McDonald C.L. (2008). Assessment of seed shattering resistance and yield loss in five oilseed crops. Canadian Journal of Plant Science. 88: 267-270.

Heitholt, J.J., Egli, D.B. and Leggett, J.E. (1986). Characteristics of reproductive abortion in soybean. Crop Science. 26: 589-595.

Jadhav, S.J., Sonone, A.H., Aher, R.P. and Dahat, D.V. (2001). Variability and character association in rice bean [*Vigna umbellata* (Thumb) Ohwi and Ohasi]. Legume Research. 24(2): 105-108.

Kataliko, R.K., Kimani, P.M., Muthomi, J.W., Wanderi, W.S., Olubayo, F.M. and Nzuve, F.M. (2019). Resistance and correlation of pod shattering and selected agronomic traits in soybeans. Journal of Plant Studies. 8: 39-48.

Krisnawati, A. and Adie, M.M. (2017a). Characterization and performance of agronomic characters of soybean genotypes resistant to pod shattering. Biodiversitas. 18: 1158-1164.

Krisnawati, A., Adie M.M., Soegianto, A., Waluyo, B. and Kuswanto. (2019a). Pod shattering resistance and agronomic traits in F5 segregating populations of soybean. SABRAO Journal of Breeding and Genetics. 51: 266-280.

Krisnawati, A. and Adie, M.M. (2017b). Identification of soybean genotypes for pod shattering resistance associated with agronomical and morphological characters. Biosaintifika 9: 193-200.

Krisnawati, A., Soegianto, A., Waluyo, B. and Kuswanto. (2019b). Selection of F6 soybean population for pod shattering resistance. Biodiversitas. 20: 3340-3346.

Mohammed H., Akromah R., Abudulai M., Mashark S.A. and Issah A. (2014). Genetic analysis of resistance to pod shattering in soybean. Journal of Crop Improvement. 28(1): 17-26.

Philbrook, B. and Oplinger, E.S. (1989). Soybean field losses as influenced by harvest delays. Agronomy Journal. 81: 251-258.

Rameeh, V. (2013). Evaluation of different spring rapeseed (*Brassica napus* L.) genotypes for shattering tolerance. Journal of Oilseed Brassica. 4: 19-24.

Romkaew, J. and Umezaki, T. (2006). Pod dehiscence in soybean: assessing methods and varietal difference. Plant Production Science. 9: 373-382.

Romkaew, J., Umezaki, T., Suzuki, K. and Nagaya, Y. (2007). Pod dehiscence in relation to pod position and moisture content in soybean. Plant Production Science. 10: 292-296.

Saitoh, K., Isobe, S. and Kuroda, T. (1998). Pod elongation and seed growth as inûuenced by nodal position on stem and raceme order in a determinate type of soybean cultivar. Japanese Journal of Crop Science. 67: 523-528.

Shivankar, R.S., Zode, N.G., Shivankar, S.K., Naphade, R.S. and Path, V.N. (2001). Effect of time harvest on seed quality and morphological indices of physiological maturity of soybean. Legume Research. 24(3).

Singh, R.K. and Chaudhary, B.D. (1979). Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers. 288p.

Thakare, D.S., Chimote, V.P., Adsul, A., Deshmukh, A.P. and Pulate, S.C. (2017). Molecular tagging of pod shattering tolerance trait in soybean [*Glycine max* (L.) Merrill] genotype MACS-450. Legume Research. 40(2): 224-231.

Tukamuhabwa, P., Dashiell, K.E., Rubaihayo, P. and Nabasirye, M. (2002). Determination of field yield loss and effect of environment on pod shattering in soybean. African Crop Science Journal. 10: 203-209.

Umar, F.A., Mohammed, M.S., Oyekunle, M., Usman, I.S., Ishaq, M.N. and Dachi, S.N. (2017). Estimates of combining ability for resistance to pod shattering in soybean [*Glycine max* (L.) Merrill] genotypes. Journal of Plant Breeding and Crop Science 9: 217-223.

Vairam, N., Lavanya, S.A. and Vanniarajan, C. (2017). Screening for pod shattering in mutant population of mungbean [*Vigna radiata* (L.) Wilczek]. Journal of Applied and Natural Science 9: 1787-1791.

Yue, J., Ma, Y.F. and Gao, Q.Y. (2006). Pod shattering character in main soybean cultivars of Huang-Huai-Hai soybean region of China. Journal of Henan Agricultural Sciences. 35: 56-59.