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Study on Seed Size Variation in Soybean (*Glycine max* L. Merr.) and its Correlation with Yield

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Abstract

The present research aimed during June-September, 2016 at the RRS (NAZ) farm, BCKV, Gayeshpur, Nadia, West Bengal, India to select promising soybean genotypes based on seed size and yield. Twenty-five soybean genotypes were grown and evaluated for the seed area (mm^2), pods $plant^{-1}$, seeds pod^{-1}, 100 seed weight (g), and seed yield $plant^{-1}$. Measurement of seed size was done in terms of seed area (mm^2) using BioVis® surface area meter. The study revealed significant genetic variability in terms of seed size among the genotypes. The average seed area (mm^2) along with yield and yield attributing characters were compared. The average seed size ranged from 31.94-51.72 mm^2 while seed yield $plant^{-1}$ had a range of 20.9-45.2 g. The genotype PS1042 was found to be very bold seed having a seed area of 51.72 mm^2 along with PK416 and PK564, which showed 51.20 and 50.09 mm^2 seed area respectively.On the contrary, JS9752 was categorized as the genotype with the smallest seed size; 31.94 mm^2 along with PK 327 (33.17 $mm^{2)}$). Seed size exhibited a significant positive correlation with 100 seed weight and seed yield $plant^{-1}$. The regression curves also revealed the pattern of contribution seed area had on yield and the yield parameters. The results of this study indicated seed size as an important parameter to be considered as one of the most reliable selection indices while breeding for high yielding soybean varieties.

Keywords: Soybean, seed weight, clustering, regression, seed area, correlation

1. Introduction

Soybean (*Glycine max* L.), is a grain legume, native to Eastern Asia, globally popular for its dual-purpose consumption as pulse and oilseed, and a major source of plant-based protein. Soybean grains are heavily enriched with 30–45% essential amino acids rich protein with along 15–22%. oil content (Olena et al., 2020). Althoug soybeans have deficiency in methionine, the sufficient lysine content in soybean can help overcome the lysine deficiency forwarded by cereals (Martinez-Padilla et al., 2020). Besides vegetable soybean, soy products like soy flour, soy protein, soy milk, tofu, soy sauce, and soybean oil are intensively marketed in Western countries as well as in Asia (Rizzo and Baroni, 2018). Soybean was introduced in India from China and ever since India has been considered as its secondary centre of domestication after China (Singh and Hymowitz, 1999). India is the fifth-largest producer of soybean in the world (Agarwal et al., 2013). According to Biswas (2018), 23-37 % of the Indian population is vegetarian, more than the rest of the world population (Edelstein, 2013) and that makes soybean the largest alternative protein source in India. Currently occupying an 11.40 million ha area in the country (Soybean outlook, 2020), soybean has achieved considerable agricultural importance in India (Agarwal et al., 2013). India is the third-largest soya oil importer in the world and a major exporter of soya meal to many Asian countries. Although soybean has emerged in India as a major oilseed crop over a very short period (Kathmale et al., 2013) the trend of using soybean as food source is still weak(Bhatnagar and Joshi, 2004). With an elevated demand-supply ratio of vegetable oil in the country along with food-grade soybean, soybean yield improvement needs focused breeding programmes. Seed size is not only an important yield component (Zhang et al., 2016), but also is a target for breeding and market preference (Xu et al., 2011). Seed size character in soybean is polygenic and determines seed composition like protein and oil content, quality, and appearance (Hu et al., 2013, Sharma et al., 2014). Seed size and seed weight is greatly influenced by genotype × environment interactions (Gill et al., 2020).The seed size is determined by the endosperm and embryo development, premature endosperm cellularization causing smaller seeds while delayed endosperm cellularization causing larger seeds inside the pod (Cheng et al., 2014, Li et al., 2019). The best quality vegetable soybean, tofu, soy milk is mainly produced from large-seeded soybeans (Whiting et al., 2020). The

increased seed size in soybeans is reported to have a higher total amount of monosaturated oils, as well as improved strength of tofu (Kering and Zhang, 2015). Seed size has an important role to play in shaping the ultimate yield (Niu et al., 2013) and seedlings from large seeds, are reported to be highly vigorous with better stand (Place et al., 2011). However, some other results are there reporting better vigour and germination in small and medium-sized seeds (Lamichaney et al., 2017).

Seed weight has been extensively studied as a key factor for seed size variation over the years. Earlier, Tiwari et al. (1978) grouped twenty-one soybean varieties into three groups viz.,- small, medium, and bold based on their test seed weight. However, no other seed size measurements apart from seed weight have been reported to better explain the role of seed size on yield and yield attributing parameters (Tumpa et al., 2021). In this study, soybean seed size has been measured in terms of seed area which providing insight about true seed size measurement and it was found to be contributing significantly to yield parameters.

2. Materials and Methods

2.1. Plant materials and growing conditions

The study was conducted with 25 soybean genotypes (Table 1) comprising National varieties, State-level varieties and indigenous varieties at the RRS (NAZ) farm, BCKV, Gayeshpur, Nadia (22.95°N, 88.49°E and 11m above MSL) during June-September, 2016. The soil is new alluvial and it is of sandy-loam texture with medium to low fertility level. 25 soybean genotypes were sown with a 35 cm ×10 cm spacing in a 3 m width plot, with two rows for each entry following randomized block design with 3 replications. Normal fertilizer dosage was applied @ 20:80:40 Kg ha^{-1} (N: P: K) as basal dose before sowing. Three random plants were selected from each genotype from each replication for the data collection on various agronomic and seed parameters. Genotypes were evaluated for the seed area (mm^2), 100 seed weight (g), and seed yield $plant^{-1}$.

2.2. Measurement of seed size

Seed size measurement was taken from the matured seeds of each genotype after harvesting and drying. The standard for seed size measurement was based on a sample group of twelve random seeds from every genotype and was subjected to seed area measurement using BIOVIS® apparatus, Expert Vision Lab private ltd., India. The BIOVIS® PSM offers a digital image analysis of the morphological area of each and individual seed under study. Seeds of each genotype were imaged with their length and width axis visible in resting position taking special care that the seed image did not skew the dimensions of the seeds. The seed area was measured in millimeter square (mm^2). Based on the replicated data mean and calculated centroids, the twenty-five varieties were grouped visually into three classes of seed size as observed: small, medium, and bold.

2.3. Statistical analysis

Data were analyzed using the randomized block design and the range of observations along with the mean values±SE was compared across the genotypes. Single-point analysis of variance (ANOVA) was carried out in GraphPad Prism8 software. The phenotypic (PCV) and genotypic (GCV) variances were analysed and compared using the critical differences at a 5% level of significance. The assessment of variability was analysed using "R-studio version 1.4.1717". Pearson coefficient of correlations were calculated as well as a graphical representation of the relationships between each pair of the characters were built.

Table 1: List of 25 soybean genotypes studied for seed area and yield parameters

Sl. No.	Genotype name	Sl. No.	Genotype name	Sl. No.	Genotype name	Sl. No.	Genotype name	Sl. No.	Genotype name
1.	RKS-18	6.	RAUS-5	11.	PS-1241	16.	JS-20-29	21.	Alankar
2.	NRC-37	7.	PS-1042	12.	JS-335	17.	MAUS-71	22.	Bragg
3.	PS-19	8.	JS-9752	13.	IndiraSoya-9	18.	PK-1024	23.	PK-262
4.	PK-327	9.	Shilajeet	14.	PS-1029	19.	PK-472	24.	Ankur
5.	Kalitur	10.	PK-564	15.	PS-1347	20.	PK-416	25.	PK-1092

3. Results and Discussion

3.1. Evaluation of 25 soybean genotypes in terms of seed area and yield parameters

Seed size is one of the major components that attributes to soybean performance and productivity (Jonson et al., 2001, Harnowo et al., 2004). Visible differences in seed size were observed among the 25 soybean genotypes under study. To determine whether soybean seed size has any influence over soybean production, the seed area (mm^2) of 25 soybean genotypes was measured as an indication of seed size and the average seed area was compared with pods number $plant^{-1}$, seed numbers pod^{-1}, 100 seed weight (g) and average seed yield $plant^{-1}$ (g) of respective genotypes in Table 2. A wide range of variation was observed among the genotypes in terms of seed shape from 31.94-51.72 mm^2 as well as for pods $plant^{-1}$ (44.2-73.8), seeds pod^{-1} (0.92-1.94), 100 seed weight (11.0-16.0 g) and seed yield $plant^{-1}$ (20.9-45.2 g). The

genotype PS1042 showed, the very bold seed having a seed area of 51.72 mm^2 along with PK416 and PK564, which showed 51.20 and 50.09 mm^2 seed area respectively.On the contrary, JS9752 was categorized as the genotype with the smallest seed size; 31.94 mm^2 along with PK 327 which showed an almost similar seed area of 33.17 mm^2 (Table 2). The maximum 100 seed weight was recorded for the genotype PS-1042 (16.0 g) which also showed the boldest seed size while the highest seed yield was observed for the genotype Ankur (45.2 g) followed by Kalitur (41.9 g). The maximum numbers of pods produced on a single plant were observed in Kalitur (73.8) while the highest numbers of seed in a pod were observed to be 2 in NRC 37 and PS 1029. The single-point ANOVA analysis (Table 3) were done to explain the significant variations present among the twenty five genotypes for all the five characters including seed yield $plant^{-1}$ and seed area (mm^2). The results from the ANOVA showed the presence of significant genotypic variation characters which indicates selection of genotypes is feasible considering any of these parameters.

Table 2: Comparison of average seed area, yield and other yield attributing traits for the twenty five soybean genotypes

Sl. No.	Variety	No. of pods $plant^{-1}$	No. of Seeds pod^{-1}	100 Seed weight (g)	Seed yiel $plant^{-1}$ (g)	Seed area (mm^2)
1.	RKS 18	46.0±0.17	1.63±0.10	13.2±0.22	23.7±1.95	42.1±1.06
2.	NRC 37	45.7±0.19	1.94±1.03	12.9±0.28	27.7±2.47	43.5±0.89
3.	PS 19	45.2±0.40	1.75±0.41	11.2±0.21	24.9±1.89	42.7±0.87
4.	PK 327	54.4±0.20	1.6±0.18	11.0±0.30	29.3±2.65	33.2±1.42
5.	Kalitur	73.8±0.05	1.85±0.54	11.9±0.22	41.8±1.96	49.5±0.21
6.	RAUS 5	48.1±0.35	1.00±0.18	12.7±0.15	28.9±1.28	45.9±0.95
7.	PS 1042	49.5±0.23	0.92±0.04	16.0±0.22	29.2±1.99	51.7±1.51
8.	JS 9752	62.4±0.21	1.45±0.47	14.3±0.21	35.3±1.88	31.9±1.40
9.	Shilajeet	44.2±0.12	1.89±1.04	13.7±0.25	21.3±2.24	41.4±0.95
10.	PK 564	44.5±0.30	1.88±0.52	15.0±0.14	37.2±1.26	50.1±1.13
11.	PS 1241	44.8±0.33	1.68±0.37	14.4±0.15	31.6±1.34	44.8±0.81
12.	JS 335	61.1±0.11	1.36±0.09	13.7±0.22	31.0±1.96	43.5±0.61
13.	Indira Soya 9	61.8±0.28	1.37±0.43	13.7±0.15	32.3±1.32	41.9±0.55
14.	PS 1029	56.0±0.34	1.92±0.57	13.8±0.14	34.9±1.21	49.2±0.45
15.	PS 1347	60.8±0.19	1.85±0.61	12.6±0.11	33.5±1.00	41.1±0.49
16.	JS 20-29	47.5±0.33	1.65±0.86	13.6±0.26	25.0±2.31	39.7±0.40
17.	MAUS 71	67.0±0.11	1.25±0.47	12.5±0.15	20.9±1.33	41.4±0.50
18.	PK 1024	52.8±0.18	1.48±0.89	13.5±0.15	33.6±1.30	38.4±2.00
19.	PK 472	61.4±0.10	1.14±0.49	14.9±0.22	38.7±1.95	47.2±0.42
20.	PK 416	56.2±0.15	1.34±0.28	14.5±0.21	30.4±1.82	51.2±0.30
21.	Alankar	49.8±0.13	1.36±0.17	13.6±0.29	24.2±2.59	41.7±0.91
22.	Bragg	54.1±0.23	1.4±0.37	14.4±0.19	35.8±1.66	49.7±1.82
23.	PK 262	55.6±0.09	1.5±0.89	12.1±0.15	23.1±1.30	40.9±0.92
24.	Ankur	57.7±0.21	0.97±0.45	12.8±0.23	45.2±2.04	49.1±1.32
25.	PK 1092	54.0±0.08	1.13±0.20	14.3±0.21	35.6±1.90	49.6±1.25
CD (p=0.05)		0.16	0.48	0.09	0.76	1.60
SEm±		0.05	0.17	0.03	0.27	0.56
GCV		14.4	17.7	8.76	20.40	11.9
PCV		26.8	26.3	11.23	23.45	12.1

Mean±SD, CD: Critical difference, SEm±= Standard error due to mean, GCV: Genotypic coefficient of variance, PCV: Phenotypic coefficient of variation

The genotypic (GCV) and phenotypic coefficient (PCV) of variations were also calculated for each of the five characters (Table 2). The genotypic (14.4) and phenotypic coefficients (26.8) conclude little to moderate environmental effect for pods plant^{-1}. The seeds pod^{-1} has considerable difference between GCV (17.7) & PCV (26.3) along with considerable environmental effect. The 100-seed weight showed a low to moderate genotypic (8.76) and Phenotypic coefficients (11.23) in close proximity. Seed yield plant^{-1} showed high Genotypic (20.40) and phenotypic (23.45) coefficients. For seed area also, the genotypic (11.9) and phenotypic (12.1) coefficients of variance are in close proximity. A high heritability of 84.0% was observed for this character. Selection is highly recommended for all the five characters with an indication of maximum success in selection for seed area and seed yield plant^{-1}.

Table 3: Mean squares (ms) of seed area, 100 seed weight, and seed yield plant^{-1} from single-point anova analysis considering 25 soybean genotypes as treatments

Source of Variation	DF	Mean Squares				
		Pods plant^{-1}	Seeds pod-1	100 seed weight (g)	Seed yield plant-1 (g)	Seed Area (mm2)
Replication	2					
Genotype	24	183.26**	0.29**	4.154**	120.1**	83.47**
Error	48	0.01	0.08	0.6959	27.33	1.072

(Significance level: *: p<0.05; **: p<0.01; ***: p<0.001)

3.2. Correlation

The correlation coefficient is an important statistical analysis that gives the degree of association among various characters. To understand how the changes in seed area influence soybean yield and yield attributing parameters, a correlation coefficient analysis was carried out (Figure 1) and seed area was found to be significantly correlated with seed yield plant^{-1} and 100 seed weight (r=0.41 and 0.44, respectively). Though the 100 seed weight showed a positive correlation with seed area, however, any significant correlation value with seed yield plant^{-1} was not observed. Seeds pod^{-1} do not show any significant correlation with any of the other four characters. The pods plant^{-1} show a significant positive correlation with seed yield (0.42). This indicates an increase in seed size is associated with a direct increase in seed yield but a higher 100 seed weight does not always account for an improved yield.

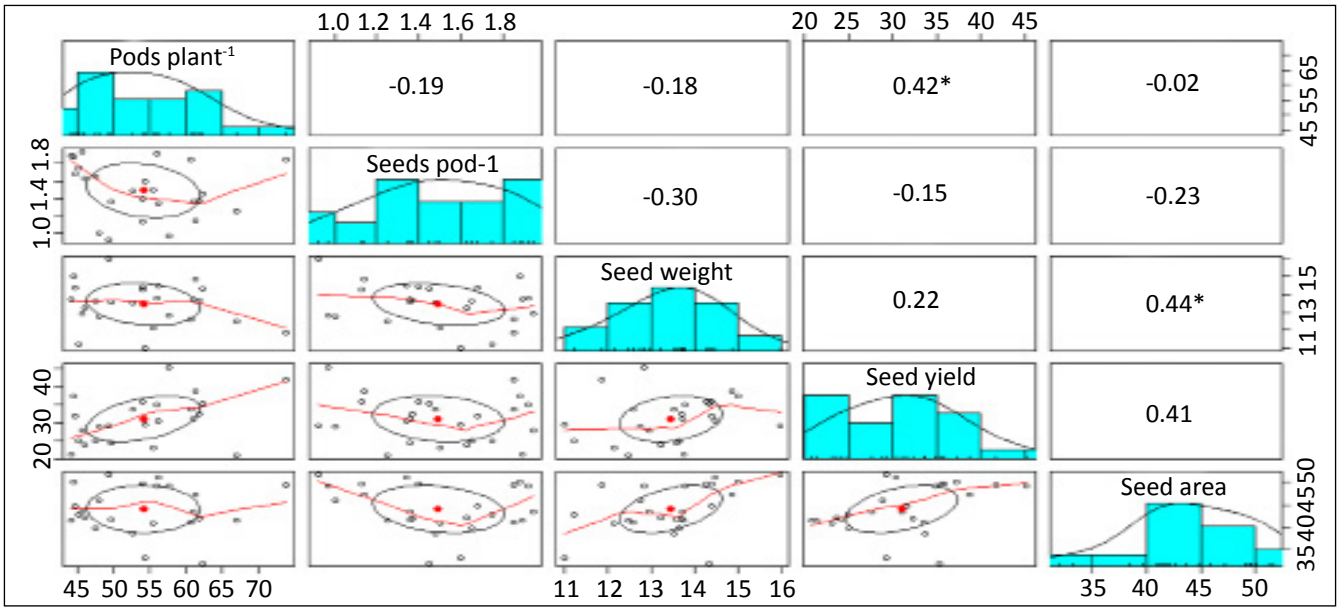

Figure 1: Scattered distribution of individual characters for respective 25 soybean genotypes and correlation analysis among them. (*: p<0.05, **: p<0.01, ***: p<0.001)

4. Conclusion

Seed size of soybean found to be significantly correlated with both 100 seed weight and seed yield plant^{-1}, and also was found to be a positively contributing variable towards these yield attributing traits, it might be an important and feasible character to be considered while breeding for high yielding varieties with improved seed qualities.

5. Future Research

Seed size is an important parameter for improvement of Soybean which needs elaborate study at molecular level in future.

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