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Expression of four-seeded pod in soybean

Four-seeded pod (SP) was expressed in all the 15 nodes of the soybean variety JS 90-41 with overall frequency of 42% and high expression of 68% in distal one-third part of the plant and specifically at the 14th node (80%). Maximum seed weight (115 mg) was recorded in two-, three- and four-SP located on node 3rd and 5th. The mean seed weight of four-SP was 96 mg, which was 6 and 5 mg less than the mean seed weight of three- and two-SP. Four-SP had 78 mg gain over three-SP; 182 mg gain over two-SP and 288 mg gain over one-SP. There was significant increase in seed yield with the increase in the frequency of four-SP in comparison to three- and two-SP. The overall plant basis four- and three-SP follow 1 : 1 ratio ($\chi^2 = 2.9$) with 3 : 1 ratio in distal; 1 : 1 middle and 1 : 3 basal parts. Penetrance of 4 SP was nearly 50% at the plant level, with high expressivity in the distal, but low in the basal part of the plant. Higher yield of soybean may be achieved through hybridization between lines that have heavy top and heavy bottom with high penetrance of four-SP.

Seed per pod and its weight are the important yield-contributing traits of soybean (*Glycine max* (L.) Merrill), with peculiar phenotypic variable expressivity. Expression of 2–3 seeds/pod is common in soybean. The most popular variety of soybean in India, JS 335 is a puberulent and purple-flowered variety with more frequency of three-SP in comparison to two-SP, whereas the other variety JS 71-5 (denotified) had more frequency of two-SP puberulent pod in comparison to three-SP[1]. A few plants with increased frequency of four-SP were identified in a segregating generation derived from the interspecific cross of cultivated soybean, *G. max*, with its proposed wild progenitor *Glycine soja* (Seib. & Zucc.)[2]. One of its lines was notified as JS 90-41. The inheritance of four-SP in crosses originating from an EMS-derived mutant with its parental cultivar, indicated control of single recessive locus with a segregation ratio of 3 : 1 (low to high seeds per pod values) with confirmation by subsequent analysis of the $F_{2:3}$ families[3]. Morphological marker, narrow leaflet and microsatellite marker Sat_107 had close linkage with the locus responsible for four-SP (3.2 ± 1.11 cM) and both were effective in selecting the four-SP trait, although with different efficiencies[3]. From the breeding point of view, the number of seeds per pod and its weight

Table 1. Difference in mean weight (mg) of seeds formed in four-, three-, two- and one-seeded pod (SP) in soybean

Number of seeds/pod	Mean weight of single seed (mg)* (gain or loss in comparison to seeds/pod)			
	4	3	2	1
4	**096**			
3	–06	**102**		
2	–05	+01	**101**	
1	00	+06	+05	**096**

*Diagonal bold value.

Table 2. Total gain/loss (mg) by the extra seeds formed in four-, three- and two-SP in soybean

Number of seeds/pod	Total gain/loss (mg) (Number of seeds/pod)		
	4	3	2
3	+78 (–18 + 96)		
2	+182 (–10 + 192)	+104 (+02 + 102)	
1	+288 (00 + 288)	+201 (+06 + 204)	+106 (+05 + 101)

Frequency of pod as number of seed		
Seed pod^{-1}	Frequency	Node
4	75.0	
3	25.0	15
2	00.0	
1	00.0	
4	80.0	
3	20.0	14
2	00.0	
1	00.0	
4	71.0	
3	29.0	13
2	00.0	
1	00.0	
4	68.0	
3	25.0	12
2	6.25	
1	00.0	
4	61.0	
3	33.0	11
2	05.5	
1	00.0	
4	50.0	
3	36.0	10
2	09.0	
1	04.5	
4	55.0	
3	35.0	9
2	13.5	
1	05.0	
4	45.0	
3	27.0	8
2	13.5	
1	13.6	
4	63.0	
3	37.0	7
2	00.0	
1	00.0	
4	28.0	
3	46.0	6
2	26.0	
1	03.6	
4	26.0	
3	47.0	5
2	26.0	
1	00.0	
4	41.0	
3	41.0	4
2	18.0	
1	00.0	
4	31.0	
3	53.0	3
2	16.0	
1	00.0	
4	33.0	
3	56.0	2
2	21.0	
1	05.0	
4	21.0	
3	58.0	1
2	11.0	
1	11.0	

*Position of seed from peduncle.

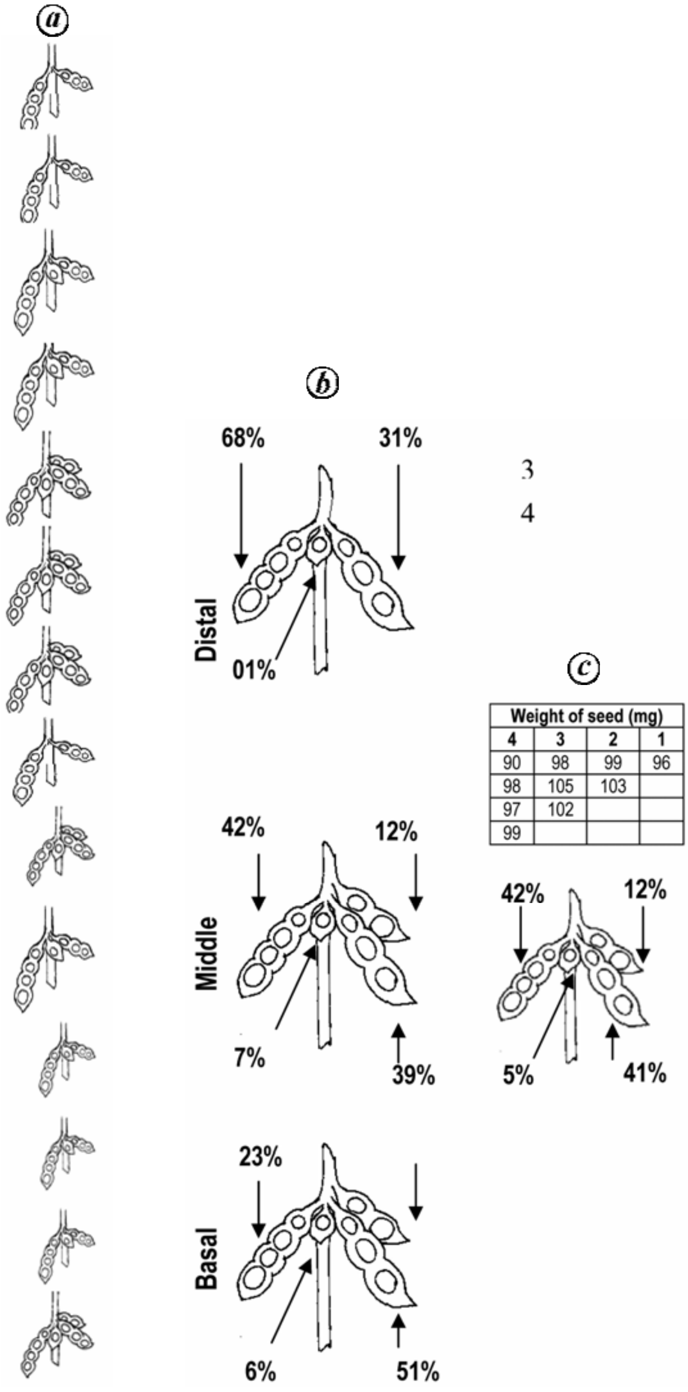

Figure 1. Percentage distribution of four-, three-, two- and one-seeded pods (SPs) along with average weight of individual seed (mg) according to: (***a***) Node-wise performance on the plant; (***b***) Average frequency of four-, three-, two- and one-SP in the distal, middle and basal parts of the plant; and (***c***) Mean performance of the plant with overall percentage of four-, three-, two- and one-SP.

has a significant and positive relevance as a quantitative yield component. A study was therefore undertaken to investigate the expressivity of the characters and their relationship with seed yield.

Twenty healthy, mature plants of JS 90-41 were selected randomly at the time of harvesting in 2007 and 2008. The frequency of four-, three-, two- and one-SP at each node was recorded by preparing the sketch of the plant. Pods located on

Table 3. Penetrance of four- and three-SP in various parts of the soybean plant

Observation	Ratio (4 : 3)	Observed value 4	Observed value 3	Expected value 4	Expected value 3	χ^2	Penetrance (%) 4	Penetrance (%) 3
Distal part	3 : 1	63	31	75	25	1.92	67.02	32.97
Middle part	1 : 1	42	39	50	50	0.32	51.85	48.14
Basal part	1 : 3	23	51	25	50	0.1	31.08	68.91
Total plant	1 : 1	42	41	50	50	2.9	50.60	49.39

Table χ^2 value at 1 d*f*, 5% 3.84; 1% 6.64.

branches were also numbered, and the weight and frequency were added to the respective node. Weight of the individual seed according to the location on the pod and location of the pod was measured by numbering each seed with the help of a marker and recording the weight. On the basis of these traits, the distribution of pods within the plant and significance of extra seeds in four-SP were determined. The whole plant was divided into three parts; distal, middle and lower according to the plant height. Ratio of three- and four-SP was tested by chi-square test on individual plant basis.

Frequency – Variety JS 90-41 had mean 15 nodes (Figure 1 *a*) with the expression of four-SP in each node and the highest frequency (80%) at the 14th node (second node from the top) and the lowest on the basal node. Whereas the frequency of three-SP was highest (58%) at the first node towards the base and lowest (20%) at the 14th node. Two-SP was not expressed in the distal one-third part (Figure 1 *b*). The frequency of three-SP (Figure 1 *b*) was higher in the basal one-third part (51%) than four-SP (23%); in the middle portion, it was nearly equal; however, at the distal one-third part the frequency of four-SP was higher (68%) than the three-SP (31%). The observation revealed that the variety had a mean of 42% and 41% for four- and three-SP respectively (Figure 1 *c*).

Seed weight – The weight of the seed located towards the stylar end of the pod had maximum mean weight irrespective of the number of seeds/pod (Figure 1 *c*). Maximum 115 mg weight was recorded in two-, three- and four-SP located on the third and fifth nodes (Figure 1 *a*) and minimum 77 mg in the first seed (towards the peduncle) of four-SP located on the 14th node. The mean weight of four-SP ranged from 90 to 99 mg, i.e. from peduncle to stylar; in three-SP 98 to 105 mg and in two-SP from 99 to 103 mg. The mean seed weight of four-SP was 96 mg, which was 6 and 5 mg less than the mean seed weight of three- and two-SP, whereas the mean seed weight of three-SP (102 mg) was 1 mg higher than two-SP (Table 1). Four-SP had 78 mg gain over three-SP; 182 mg gain over two-SP and 288 mg gain over one-SP. Whereas three-SP had 103 mg gain over two-SP (Table 2). The present study reveals that with increase in the frequency of four-SP in comparison of three- and two-SP, there is significant increase in seed yield; therefore the trait may be altered genetically.

On overall plant basis, the four- and three-SP followed a 1 : 1 ratio. When observation was recorded by portioning the plant into three parts (basal, middle and distal), it was found that in the distal one-third part of the plant four- and three-SP followed 3 : 1 ratio; 1 : 1 in the middle part; and 1 : 3 in the basal part, i.e. more number of three SPs in comparison to four-SP (Table 3). It revealed that the gene responsible for four- and three-SP follows a certain ratio with differential expressivity. The gene responsible for four-SP had low expressivity (25%) at the basal part of the plant, equal (50%) in the middle but higher (75%) at the distal part of the plant in relation to three-SP. Four- and three-SP did not differ in the penetrance as both have nearly 50% penetrance at the plant level. However, four-SP had high penetrance in the distal part (67%), whereas low at basal part (31%). Thus four- and three-SP with low penetrance appeared to be weak or instable at different stages of development. It revealed that higher yield might be achieved through hybridization between lines that have heavy top and heavy bottom with high penetrance of four-SP.

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