Vegetable Science (2021) 48 (2) : 172-177

Single dominant gene controls glabrous trait in vegetable soybean accession 'AGS-406'

Jyoti Devi*, Vidya Sagar, Rakesh K Dubey, Ravindra K Verma, Prabhakar M Singh and Tusar K Behera

Received: November 2021/ Accepted: December 2021

Abstract

The glabrous pods or grey pubescence is highly preferred trait for the vegetable soybean cultivars since the appearance of the cooked pods is clean compare to brown or dark pubescence pods. The genetic control of trichomes is thoroughly studied in cotton and *Arabidopsis* with very limited information in soybean particularly in variants of vegetable types. Inheritance of this traits was worked out by utilizing glabrous vegetable soybean genotype 'AGS-406' that was crossed with normal pubescence cultivar 'AGS-346' and 'Swarna Vasundhara', the commercially released cultivar of vegetable soybean in India. The observed segregation ratio of the F_2 population fitted to the expected ratio of 3:1, and the glabrous phenotype was found to be controlled by a single dominant gene.

Keywords: Inheritance, Trichome, Pubescence, Glabrous, Vegetable Soybean, Breeding

Introduction

Vegetable soybean [*Glycine max* (L.) Merrill] has started gaining popularity among its growers and consumers across the world, due to its rich harvest and healthy nutritional profile (Devi et al. 2020). The increasing literature on their purported health benefits and capacity to combat range of hazardous diseases has attracted people's attention for this special vegetable across the globe. The health benefits of soy and soy phytochemicals includes prevention of cardiovascular disease, obesity-related metabolic syndrome, breast and prostate cancers and other chronic diseases. It contains all essential amino acids and considered as a complete protein supplement, which makes it equivalent to the products like meat, milk and eggs. In comparison to its grain counterparts, which is mainly grown as oilseed crop (Yashpal et al. 2015), green-pods of vegetable soybean can be consumed in various ways such as snacks, salad, etc., while its green-seeds (beans) can be consumed like peas. Besides its rich nutritional architecture, vegetable soybean has also vital contribution in maintaining soil fertility and crop diversification. In India, Jharkhand is the only state where commercial cultivation of this crop has started recently, and it is becoming popular especially among children. To make it more suitable for consumption as vegetable, specialty characters were introduced into vegetable type soybean through traditional genetic breeding, which holds the unique combinations of various horticultural and biochemical traits.

The commonly grown soybean varieties are having a characteristic feature of dense covering of erect hairs or trichomes on the stem, leaf and pods. These are the specialized structures that develop on the surface of stems, leaves, flowers, pods, seed coat, fruits and roots of the plants. Trichome morphology, varying greatly between species, includes types that are unicellular, multicellular, glandular, non-glandular (as in soybean), single stalks (soybean), or branched structures (Werker 2000). Furthermore, Bernard and Singh (1969) reported considerable variation among varieties of soybeans with respect to size, shape, durability and distribution of plant hairs including *P1* (glabrous), *pc* (curly pubescence), *Pd* (dense pubescence), *Ps* (sparse pubescence) and *p2* (puberulent). Research has shown that each of the five types differed from the normal by a single gene pair and that the five loci separated independently (Yu et al. 2020). Developing dark-green unblemished green pods preferably with no (glabrous pods) or sparse grey pubescence is one of the major breeding objectives in vegetable soybean. The glabrous or grey pubescence is preferred for the vegetable soybean cultivars since the appearance of the cooked pods is clean compare to brown or dark pubescence pods. The trait has its own

ICAR-Indian Institute of Vegetable Research, Varanasi–221305, Uttar Pradesh

*Corresponding author, Email: jyoti17iivr@gmail.com

significance as it affects diverse agronomic characters such as seed weight and yield, insect resistance, transpiration and leaf temperature regulation of plants (Hunt et al. 2011; Yu et al. 2020). Their role in insect resistance is much more elaborate, as some insect-resistant soybean varieties had smooth leaf surface and thin trichomes while some insect-sensitive soybean varieties had rough leaf surface and dense trichomes (Komatsu et al. 2007; Yang and Ye 2013; Hunt et al. 2011). The genetic control of trichome initiation and development has been studied broadly in cotton and *Arabidopsis*. However, genetics of trichomes has not been studied extensively in soybean, especially the vegetable types. The present investigation is carried out to work out the inheritance of glabrous pods in vegetable soybean genotypes using the two cross combinations including their reciprocals. This study will lead to knowledge about the breeding procedure to develop the glabrous pods suitable for vegetable purpose.

Material and Methods

Locations of study: The present investigation was undertaken at the Experimental Farm of ICAR–Indian Institute of Vegetable Research Varanasi located at 82°52'37'' E and 25°18'21'' N at an elevation of 83 m above the mean sea level during 2018-19 to 2019-20. Agro–climatically, the location represents the Middle Gangetic Plain Region of India, characterized by a humid subtropical climate with an average rainfall of approximately 998 mm per annum. The soil of the experimental plot was with neutral with pH (7.4), while soil texture was silt–loam having 0.45% organic carbon, 178 kg ha^{-1} available nitrogen, 52.0 kg ha^{-1} available phosphorus (P_2O_5), and 340 kg ha^{-1} available potash (K_2O).

Experimental materials: To analyse the inheritance of the glabrous trait, four cross combinations were made (including two reciprocals) by involving the glabrous parent *viz.*, AGS-406 that was crossed with normal pubescence genotype AGS-346 and the cultivar *Swarna Vasundhara* (Figure 1). The parents AGS-406 and AGS-346 were augmented from World Vegetable Regional Center for South Asia, (ICRISAT), Patancheru, while the cultivar *Swarna Vasundhara* was obtained from ICAR Research Complex for Eastern Region, Patna. The crosses were made during *kharif, 2018-19* and half of the F_1s were advanced to F_{2S} during Feb-May 2019-20. The crosses and F_I were raised under the protected structure to ensure minimum population size of the F_2s. The three parents, remaining F_1s and advanced F_{2S} were evaluated under normal field condition during *kharif,* 2019-20 from July to October 2020, and standard cultural practices were followed to raise a healthy crop. All the plants were space planted at 30 cm distance to each other, while row to row spacing was kept at 60cm.

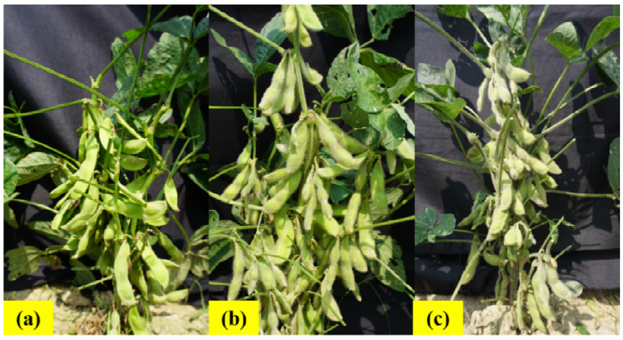

Figure 1: A close view to morphological appearance of plants and pods of three parents (a): AGS-406; (b) AGS-346 and (c) Swarna Vasundhara

Recording of observations: The data was recorded on the three parental lines along with the cultivar 'Palam soya', a dual-purpose soybean cultivar for phenotypic variation for flower and pod colour, absent/presence of pubescence on plants and pods, its type, seeds coat colour and surface lusture, leaflet shape and overall growth habit of the plants. The morphological characterization was followed from soybean descriptor as described by International Board for Plant Genetic Resources (IBPGR 1984). Among the horticultural traits, observations were made on days taken to first flowering (DTF; No.), days taken to R6 stage (DToR6; No), plant height at R6 stage (PH; cm), leaf length width ratio (LLW; cm), pod length (PL: cm); pod width (PW; cm); average pod weight (APW; g), pods per plant (PPP; No.), 100-green seed weight (100-GSW; g); days taken to flower termination (DTFT; NO.), pod yield per plant (PY/P; g) and 100-dry seed weight (100-DSWg).

Statistical analysis: To analyse the similarities and differences in the mean values of the studied traits, Tukey's test was used. Also, inheritance studies were performed using $\div^2$ test for glabrous and pubescent types of pods.

Results and Discussion

Performance of genotypes for various horticultural traits: The parameters used to evaluate the quality of vegetable soybean are distinct from those used to grade grain soybeans. To make it more suitable for consumption as vegetable, specialty characters were introduced into vegetable type soybean through traditional genetic breeding, which holds the unique combinations of various horticultural traits. When bred for vegetable purpose, the length and width for green

Table 1: Morphological Characterization of parents along with the dual-purpose cultivar 'Palam Soya'

Genotypes & Traits	ASG-406	AGS-346	Swarna Vasundhara	Palam Soya
Flower Colour	Purple	Purple	Purple	Purple
Pubescence	Absent	Present	Present	Present
Pubescence colour	-	Grey	Grey	Tawny
Pubescence type	-	Erect	Erect	Appressed
Seed Coat Colour	Buff	Green	Buff	Green
Seed Coat Surface Lusture	Dull	Intermediate	Shiny	Shiny
Leaflet Shape	Ovate	Lanceolate	Ovate	Intermediate
Plant growth habit	Erect	Erect	Semi Erect	Erect
Pod Colour	Brown	Brown	Brown	Brown

The morphological characterization was followed from soybean descriptor as described by international Board for Plant Genetic Resources (IBPGR, 1984)

pods should be Ã5 cm long and Ã1.4 cm, respectively and a packet for 500 g should at least contain 175 pods. Further, the pods should be completely green preferably with no or with sparse grey pubescence, with no hint of yellowing (Kiuchi et al. 1987; Shanmugasundaram et al. 1989).

In present study, all the genotypes showed considerable variation for trichome, leaf and seed traits that were easily recognizable with visual appraisal in the material (Table 1). The genotype AGS-406 took minimum days for first flowering and days to R6 stage when the seeds are fully developed but still green in colour (Table 2). The dual-purpose cultivar Palam Soya was found late in flowering as well to reach the R6 stage. All the genotypes were of short stature with least variation for plant height (22-42 cm), while a variation of 1.53 to 2.33 cm was observed for the leaf length width ratio. In vegetable soybean, pod length, width their weight are the key economic parameters, as these traits directly affect the quality of pods and consumers' acceptance. The genotypes AGS-406 and Swarna Vasundhara produced longer and broader pods having average pod

Table 2: Mean performance of the parents along with the dual-purpose cultivar Palam soya grown during *kharif,* 2019-20

Traits	AGS-406	AGS-346	SV	Palam Soya	R2	LSD (5%)
DTF (No.)	25.63^{b}	32.33^{ab}	39.87^{a}	40.0^{a}	0.78	2.26
DToR6 stage (No.)	56.33^{b}	63.67^{ab}	68.00^{a}	73.00^{a}	0.76	2.41
PH at R6 (cm)	22.53^{b}	32.33^{ab}	42.53^{a}	30.67^{ab}	0.75	2.91
LLW (Ratio, cm)	1.53^{c}	2.33^{a}	1.67^{bc}	2.10^{ab}	0.78	0.12
PL (cm)	4.45^{a}	4.17^{ab}	4.43^{a}	3.60^{b}	0.74	0.15
PW (cm)	1.27^{a}	1.12^{a}	1.13^{a}	0.87^{b}	0.80	0.05
APW (g)	1.77^{a}	1.67^{a}	1.67^{a}	0.87^{b}	0.87	0.10
PPP (No.)	31.57^{b}	33.60^{b}	52.00^{ab}	73.67^{a}	0.85	4.95
100-GSW (g)	45.13^{a}	40.00^{a}	41.67^{a}	20.77^{b}	0.97	1.15
DTFT (No.)	53.67^{b}	62.67^{ab}	66.33^{ab}	73.00^{a}	0.75	2.89
PY/P (g)	53.67^{a}	53.33^{a}	73.33^{a}	60.00^{a}	0.55	5.14
100-DSW (g)	26.81^{a}	16.11^{bc}	20.28^{b}	11.93^{c}	0.92	0.96

Mean followed by the same superscripts are not significantly different (p<0.05). Where, DTF: Days to Flower; DToR6 stage: Days to R6 Stage; PPP: PH: Plant Height; LLW: Leaf Length Width ratio; PL: Pod Length; PW: Pod Width; APW: Average Pod Weight; Pods Per Plant; 100-GSW: 100-Green Seed Weight; DTFT: days to flower termination; PY/P: Pod Yield Per Plant (g) and 100-DSW:100-dry seed weight.

weight of 1.77 and 1.67 g, respectively. Number of pods in these genotypes varies from 31-73, while 100 green seed from 20-45 g, showing a significant variation in these traits. However, for pod yield per plant, the genotypes do not differ significantly to each other.

Inheritance of glabrous trait: Focusing on the genetic trait of hairiness on pods, in soybeans destined for human consumption is necessary due to the relevance for product acceptability by the consumer market. The genetics of glabrous trait was studied using two cross combinations (including their reciprocals) in the F_2 generation. As reciprocals did not show any maternal inheritance/effect, so the data was combined for these crosses (Table 3). The appearance of glabrous plants in the F_1 progenies of the crosses *Swarna Vasundhara* × AGS-406 and AGS-346 × AGS-406 indicated the successful transfer of glabrous character from the male side, thereby ruling out the possibility of self-pollination during crossing programme. In reciprocals also (AGS-406 × *Swarna Vasundhara* and AGS-406× AGS-346),

Table 3: Segregation of plants for glabrous and hairy plants in two cross combinations including their reciprocals

S. No.	Crosses	Observed Plants in F_2	F_2 segregations		Fitness	χ^2 Cal	P-value (p<0.05)	Gene action
			Glabrous pods	Hairy pods				
1	SV × AGS-406	116	88	28	3:1	0.05	0.82	Monogenic dominant
2	AGS-406 × SV	156	120	36		0.31	0.58	
Total Plant Population		272	208	64		0.31	0.58	
3	AGS-406× AGS-346	58	44	14	3:1	0.02	0.89	Monogenic dominant
4	AGS-346 × AGS-406	76	58	18		0.07	0.79	
Total plant population		134	102	32		0.09	0.76	

The χ^2 tab value at one degree of freedom is 3.84 (0.05%); SV: Swarna Vasundhara

Figure 2: Segregation of Plants for Glabrous Trait in F_2 Population of AGS-406 × Swarna Vasundhara

leaf and seed characters were taken into consideration to identify the true crosses. Further, phenotypic appearance of the F_1 progenies showed that the glabrous trait to be a simple Mendelian inheritance, dominant to the pubescence. The 272 F_2 progenies derived from the cross *Swarna Vasundhara* × AGS-406 (including reciprocal) were segregated as glabrous plants (208 No.) and hairy plants (64 No.), while 134 F_2 plants (AGS-346 × AGS-406) were segregated as glabrous plants (102 No.) and hairy plants (32 No.) which fitted well to the 3:1 ratio (÷2= 0.31 and 0.21 respectively) (Table 3; Figure 2), which means that there is presence of monogenic dominance inheritance. The present finding also in agreement of sun et al. (2007) and Yu et al. (2020), who also reported glabrous phenotype controlled by a single dominant gene.

The glabrous trait in soybean was first noticed during 1923 by the two workers Nagai and Saito, in the F_2 generation of a cross between two pubescent parent genotypes from Japan. They further reported the origin of the glabrous character as a factor mutation in one of the flowers of the F_1 plants. This marked the beginning of the glabrous trait and the same material became the source of glabrous trait worldwide. Thus, all the initial glabrous strains of soybeans were from the Japan. The glabrous character was found to be controlled by single dominant gene, classically designated as P1p1. Later, single recessive inheritance of the trait was also discovered by Stewart and Wentz (1926) from the pubescent genotypes grown in USA, who designated the factor pair as p2p2. The workers also reported that the glabrous plants are much smaller than the pubescent plants, having smaller leaves and produce only a very small number of pods. Sun (2007) also confirmed monogenic dominant inheritance of this trait in soybean. The trait is also known to reduce the plant vigour in soybean cultivars (Singh et al. 1971). The reported significant differences of height in the order of glabrous, curly, sparse, normal, and dense with the glabrous shortest and dense tallest in all stages of growth; however, yields of normal, dense, and sparse were reported to be similar and superior to yields of curly and glabrous. In our study also, no yield disadvantage was observed for this trait.

Recently, Yu et al. (2020) also worked out genetic of hairy trait in a cross between soybean landrace '*Aijiaomaodou*' with normal pubescence and a glabrous soybean line '39002' and reported that glabrous genotypes was controlled by single dominant gene. They also extend their study to identify genomic location of glabrous (P1) gene that was mapped to the chromosome 9 with an interval of 2.76 Mb. Among the 551 genes in this region, four specific genes (*Glyma09G280500*, *Glyma09G282600*, *Glyma09G259400* and *Glyma09G283400*) appeared to be the most important candidate genes that are highly related to the glabrous trait. Further research into these genes might lead to the isolation and cloning of the glabrous gene, which would make vegetable soybean breeding easier.

Acknowledgement

The authors are thankful to Dr. Ramakrishnan M. Nair, Regional Director, World Vegetable Center, ICRISAT Campus, India for sharing the vegetable soybean germplasm. The authors are also thankful to Indian Council of Agricultural Research (ICAR), New Delhi for financial support.

सारांश

चमकदार फली या हरा तारूण्य सब्जी सोयाबीन किस्मों की अत्यधिक पसंद किया जाता है क्योंकि पकी हुयी फली भूरे या गहरे तारूण्य फली की तुलना में काफी साफ होती है। त्वचा रोम के आनुवांशिक नियंत्रण का कपास और मदार पर गहन अध्ययन किया गया है परन्तु सब्जी सोयाबीन में इसकी जानकारी बहुत ही सीमित है। इस लक्षण के वंशानुक्रम के अध्ययन के लिए सब्जी सोयाबीन की प्रभेद ए.जी.एस.–406 का संकरण ए.जी.एस.–346 एवं सब्जी सोयाबीन की व्यावसायिक रूप से जारी की गयी किस्म 'स्वर्ण वसुंधरा' के साथ किया गया। द्वितीयक पीढ़ी में पृथक्करण का अनुपात 3:1 पाया गया। निष्कर्ष के तौर पर पाया गया की चमकदार बाह्यदृश्य प्रारूप एक प्रमुख जीन द्वारा नियंत्रित होता है।

References

IBPGR (1984) Descriptors for Soybean. IBPGR Secretariat: Rome, Italy, pp 19–38.

Bernard RL and Singh BB (1969) Inheritance of pubescence type in soybeans: glabrous, curly, dense, sparse, and puberulent. Crop Science 9(2):192.

Devi J, Dubey RK, Singh PM and Singh J (2020) Vegetable soybean. Indian Horticulture 65(3): 130.

Hunt M, Kaur N, Stromvik M and Lila V (2011) Transcript profiling reveals expression differences in wild-type and glabrous soybean lines. BMC Plant Biol 11:145.

Kiuchi Y, Ishikawa H, Nitta N, Sasaki T and Sato T (1989) New vegetable-type soybean varieties: Iwamamekei 1, Iwamamekei 2, Iwamamekei 3, Iwamamekei 4, and C9. Iwate Kenritsu Nogyo Shikenjo Kenkyu Hokoku 28:27-39.

Komatsu K, Okuda S, Takahashi M, Matsunaga R and Nakazawa Y (2007) Quantitative trait loci mapping of pubescence density and flowering time of insect-resistant soybean (*Glycine max* L. Merr.). Genetics and Molecular Biology 30 (3):635-639.

Nagai I and Saito S (1923) Linked factors in soybean. Japanese J Bot 1:121-136.

Shanmugasundaram S, Tsou TCS and Cheng SH (1989) Vegetable soybeans in the East. In: AJ Pascale (ed), World Soybean Research Congress IV: Actas Proceedings, pp 1978-1987.

Singh BB, Hadley HH, RL Bernard (1971) Morphology of pubescence in soybean and its relationship to plant vigour. Crop Science 11: 13-16.

Stewart, RT and Wentz JB (1926) A recessive glabrous character in soybeans. Journal of the American Society of Agronomy 18:997-1009.

Sun J (2007) Heredity analysis and molecular marker study on glabrous character of soybean. M.Sc. Thesis, Jilin Agricultural University (In Chinese with English abstract).

Werker E (2000) Trichome diversity and development. Advances in Botanical Research 31:1-35.

Yang C and Ye Z (2013) Trichomes as models for studying plant cell differentiation. Cellular and Molecular Life Sciences 70:1937-1948.

Yashpal, Rathod DR, Devi J, Kumar A, Mukherjee K (2015) Genomic variation studies in *Glycine max* and *Glycine soja* using SSR markers. Current Science 109(11):1929-1930.

Yu X, Jin H, Yang Q, Fu X and Yuan F (2020) Genetic mapping of a soybean glabrous gene using specific-locus amplified fragment sequencing method. Legume Research 43:501-506.