Indian J. Genet. Plant Breed., (2024); 84(3): 482-491
https://doi.org/10.31742/ISGPB.84.3.19
ISSN: 0975-6906
www.isgpb.org

RESEARCH ARTICLE

Characterization of vegetable soybean (Edamame) germplasm and assessment of optimal food quality traits

Priya P. Pardeshi*, Priti A. Sonkamble, Darasing R. Rathod, Dhiraj R. Gangtire, Pravin V. Jadhav, Sanjay B. Sakhare, Ravindra S. Nandanwar and Philip Varghise[1]

Abstract

Vegetable soybean (*Glycine max* (L.) Merrill) stands out among pulse crops, boasting high protein content and serving as a rich source of iron and zinc. Recognizing its potential to address malnutrition and enhance nutritional security in India, the present study was conducted to screen vegetable soybean germplasm based on yield and quality attributes. A set of 35 genotypes, including advanced lines derived from the crossbreeding of grain and vegetable soybeans and varieties both types. Comparative analyses of nutritional traits at the R6 and R8 stages, as well as organoleptic parameters, were conducted. Genotypes VS-1-17-17, VS-2-141-17, and VS-5-265-17 displayed superior quality traits as compared to traditional grain-type soybeans. Notably, VS-2-141-17 stood out for exceptional nutritional and sensory attributes. Organoleptic assessments identified AGS-459, AGS-457, and AGS-450 as superior in taste, texture, and overall acceptability. The present findings offer valuable insights for future vegetable soybean cultivation and breeding in India, contributing to enhanced breeding practices. The present study may be relevant for breeders, researchers, and farmers exploring the potential of vegetable soybeans.

Keywords: Vegetable soybean, DUS traits, characterization, trypsin inhibitor, micronutrient

Introduction

India, with a population of 1.39 billion, faces significant challenges in child malnourishment, ranking 2nd globally with 47% of children affected. It ranks 15th among countries grappling with hunger. According to the World Bank and IFPRI, around 2.1 million Indian children under five years of age succumb annually to a lack of immunity against common diseases. Micronutrient deficiencies, particularly zinc and iron, are increasing among the poor. Adaptable crops that address protein malnutrition are crucial for India's cropping system. Vegetable soybeans are a remarkable crop with the potential to significantly ensure nutritional security for a larger population.

Vegetable soybean, commonly known as edamame, is a nutrient-rich food source with unique qualities. Derived from the unripe, green form of edible soybeans, edamame is distinct for its larger size, sweeter taste, tenderness, and lower trypsin content than grain soybeans. The term 'edamame' translates to 'beans on branches' in Japanese. In soybeans, the R6–R7 stage refers to the stage when seeds are immature and pods are still green (Zhang et al. 2010). It is recognized for its exceptional nutritional content, making it highly valued by breeders. With a 56% higher protein content than green peas, vegetable soybeans offer a significant protein alternative (Wolfe et al. 2018). Furthermore, as a leguminous crop, soybeans can fix nitrogen in the soil, thereby bolstering their effectiveness as green manure and contributing to sustainable farming practices. Despite its numerous advantages, edamame

Deptt. of Agricultural Botany, PGI, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444 104, Maharahtra, India.

[1]Agharkar Research Institute, Pune 411 004, Maharashtra, India.

***Corresponding Author:** Priya P. Pardeshi, Deptt. of Agricultural Botany, PGI, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444 104, Maharshtra, India, E-Mail: priya_genetics@yahoo.com

How to cite this article: Pardeshi P.P., Sonkamble P.A., Rathod D.R., Gangtire D.R., Jadhav P.V., Sakhare S.B., Nandanwar R.S. and Varghise P. 2024. Characterization of vegetable soybean (Edamame) germplasm and assessment of optimal food quality traits. Indian J. Genet. Pl. Breed., **84**(3): 482-491.

Source of support: Nil

Conflict of interest: None.

Received: Dec. 2023 **Revised:** July 2024 **Accepted:** July 2024

remains relatively unknown in India, primarily because of the absence of suitable genotypes in soybean-growing states and a lack of awareness regarding its benefits.

The primary and sustainable objective of vegetable soybean breeding is to enhance the overall quality of the crop, encompassing appearance, nutritional value, and taste, as well as to increase yield (Golicz et al. 2016; Varshney et al. 2020; Lu et al. 2022). Emphasizing taste, texture, flavor, aroma, and nutritional value, ongoing initiatives enhance the consumer acceptability of edamame in India. These endeavors not only promote a nutritious dietary choice but also contribute to sustainable agricultural practices, aligning with the broader goal of addressing malnutrition and enhancing food security in the country (Pardeshi et al. 2024). Hence, in the present study, efforts were made to categorize and assess newly developed vegetable soybean lines based on their distinct characteristics, quality traits, and adherence to DUS guidelines.

Materials and methods

Genetic material

In this study, 35 diverse genotypes were assessed, including 14 wellknown varieties of soybean and vegetable soybean along with 21 newly developed lines resulting from crosses between popular grain type and vegetable type soybeans. The vegetable soybean varieties included Swarna Vasundhara (developed at ICAR Research Complex for Eastern Region), GC-8450132-01, AGS-339, AGS-450, AGS-457, and AGS-459 (AVRDC-The World Vegetable Center, ICRISAT Campus) and HIMSO-1563 (developed by ICAR-IISR). The seed material for this investigation was obtained from the Agharkar Research Institute, Pune, Maharashtra.

Experimental condition

In 2021, a study was carried out at the Seed Technology Research Unit (STRU) in Dr. PDKV, Akola in the kharif season. The location had deep black cotton soils with a pH ranging from 7.6 to 8.1, situated at an elevation of 307.4 m, a latitude of 20.42°N and a longitude of 77.02°E. The experimental crops were spaced at 50 cm between plant rows and 20cm between plants, following a randomized block design with three replications. Basal fertilizers (30 kg N, 75 kg P2 O5, and 20 kg K2 O per hectare) were applied before sowing using urea, single superphosphate, and muriate of potash. To optimize pod production, three irrigations were administered during the post-flowering stages. Notably, no insecticides or pesticides were used in the cultivation process.

Evaluation of DUS characters

For the characterization of genotype, the descriptor of essential characters (Table 1) was used in an orderly manner as per the national test guidelines for the conduct of the test for Distinctness, Uniformity and Stability (DUS) on soybean as also suggested by Ramteke et al. (2008).

Estimation of protein and oil content

To determine protein and oil content, seeds were collected at the R6 (air-dried) and R8 stages from five representative plants in each replication. Protein content was assessed following the methodology recommended by Pardeshi et al. (2023), while the NMR method was employed for oil content estimation.

Carbohydrate content (g/100 g)

The carbohydrate (starch) content of seeds from pods harvested at the green and mature stages was determined using the anthrone reagent method. This involves extracting sugars with 80% alcohol, extracting starch with perchloric acid, and hydrolyzing starch to glucose. Glucose is then dehydrated to hydroxyl methyl furfural, forming a green product with anthrone. A preliminary Iodine test for starch was performed by soaking seeds overnight, breaking them to expose cotyledons, applying iodine solution, and observing the color change under a microscope. Starch interaction with iodine changes the color to bluish-black, indicating starch content.

Sugar content (g/100 g)

Total sugars in the edible portion were estimated using the Phenol sulfuric acid method. The Phenol sulfuric acid method for sugar estimation is a widely used technique in carbohydrate research and is attributed to Dubois et al. (1956). Sugars produce an orange-yellow color when treated with phenol and concentrated H_2SO_4, with glucose dehydrating to hydroxymethyl furfural in a hot acidic medium, forming a product with absorption at 490 nm.

Extraction and estimation of trypsin inhibitor

Soybean seeds contain anti-nutritional elements like Kunitz trypsin inhibitor (KTI), posing risks to food and feed safety. KTI, a 21.5 kDa protein with 181 amino acids, negatively impacts digestion. Heat treatment, while partially effective, leaves about 20% residues. Genetic elimination is the preferred method, avoiding additional costs. Identifying soybean genotypes for a breeding program targeting KTI reduction is crucial. The investigation assessed trypsin inhibitor content using the Kakade et al. (1974) method with some modifications and compared results with the widely used JS-335 soybean accession for clarity.

Estimation of zinc and iron contents

This study utilized atomic spectroscopy to estimate iron and zinc contents by comparing samples with respective standards. The analysis took place at the Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola, Maharashtra.

Table 1. Comprehensive DUS characterization of soybean genotypes with descriptors

S.No.	Descriptors	Particulars
1	Hypocotyl: Anthocyanin pigmentation	Absent
		Present
2	Plant: Growth type	Determinate
		Semi-determinate
		Indeterminate
3	Plant: Days to 50% flowering	Early (≤ 35 days)
		Medium (36–45 days)
		Late (> 45 days)
4	Leaf: Shape	Lanceolate
		Pointed ovate
		Rounded ovate
5	Leaf: Color	Green
		Dark green
6	Flower: Color	White
		Purple
7	Pod: Pubescence	Absent
		Present
8	Pod: Pubescence color	Grey
		Tawny (Brown)
9	Seed: Cotyledon color	Yellow
		Green
10	Plant: Height (cm)	Short (≤ 40)
		Medium (41–60)
		Tall (>60)
11	Pod: Color	yellow
		Brown
		Black
12	Pod shattering	Shattering
		Non-shattering up to 10 days
13	Plant: Days to maturity	Early (≤ 95 days)
		Medium (96–105 days)
		Late (>105 days)
14	Seed: Size (100 seed weight)	Small (≤ 10.0 g)
		Medium (10.1–13.0 g)
		Large (> 13.0 g)
15	Seed: Color	Yellow
		Yellow-green
		Green
		Black
16	Seed: Oil content (%)	Low (≤ 15.0)
		Average (15.1–18.0)
		Medium (18.1–20.0)
		High (> 20.0)
17	Seed: Protein content	Low (≤ 38.0)
		Medium (38.1–40.0)

Estimation of sensory attributes

To meet the demands of both farmers and consumers, edamame soybean cultivars must demonstrate superior agronomic performance and fulfill consumer acceptance criteria (Carneiro et al. 2020; Zhang et al. 2022). This study evaluated value-added traits by blanching samples at 100°C, followed by immediate immersion in cold water (4°C) for 1-minute. The assessment involved duplicate testing of genotypes, with Swarna Vasundhara, HIMSO 1563, and AGS 459 serving as controls. About 35 panelists from the Department of Agricultural Botany and Center of Biotechnology at Dr. PDKV, Akola, aged 22–56, conducted sensory evaluations based on appearance, aroma, taste, texture, and overall acceptability. Ratings were given on a 7-point hedonic scale as described by Ma et al. (2015). Panelists discussed each sample's attributes openly. Fragrance was determined at the R6 stage of the crop using a modified procedure from Sood and Sidiq (1978), with desirable modifications to the KOH concentration.

Statistical analysis

The analyses were conducted using the R software, specifically employing version 1.3 to 6 of the Agricolae package. For the detection of differences among the samples regarding value-added traits Duncan's multiple-range test is used.

Results and discussion

Qualitative characters are considered marker characters in the identification of soybean species and varieties, which are less influenced by environmental fluctuations. The work on inheritance and linkage studies of qualitative characters was studied by Raut (2003). The earlier published work (Satyavathi et al. 2004; Gupta et al. 2010) also substantiate that flower color, presence and absence of pod hair, hair color, and seed color were the most stable characteristics across the agroclimatic zones. To establish distinctiveness among soybean varieties, 17 characters were used (Table 2) as per the National Test Guidelines for the conduct of tests for DUS on soybeans (Anonymous 2009).

Flower characters

In this study, we observed a strong correlation between hypocotyl anthocyanin pigmentation and flower color in soybeans. Varieties with purple hypocotyls consistently exhibited purple flowers, while those with green hypocotyls had white flowers, corroborating the findings of Gupta et al. (2010). Soybean varieties in India were categorized into two main groups based on flower color: white and purple. Palmer et al. (2004) and Takahashi et al. (2008) identified six genes (W1, W2, W3, W4, Wm, and Wp) responsible for flower color. About 16 genotypes in this study displayed anthocyanin coloration in both hypocotyls and purple flowers, while the remaining white-flowered lines lacked anthocyanin coloration in the hypocotyls.

Growth characters

In our study, we identified dwarf varieties, including AGS 339, AGS-450, AGS-457, AGS 459, HIMSO 1563, and eleven lines. Medium-statured lines included VS-2-128-17, VS-2-141-17, VS-5-265-17, VS-5-266-17, and VS-5-276-17 however, the accession of vegetable soybean from Himachal Pradesh have been categorized as tall. Most vegetable-type soybeans and advanced lines displayed a semi-erect growth habit, except Swarna Vasundhara, which had an erect habit. Photoperiod-sensitive loci were noted, influencing time to flowering and maturity. GC-8450132-01 and HIMSO 1563 had medium maturity duration, but overall, all lines were considered early maturing based on days to maturity.

Leaf characters

Considering the leaf shape of Swarna Vasundhara, AGS 339 and lines VS-1-17-17, VS-5- 276-17, VS-5-265-7, VS-5- 266-17, and VS-5- 273 -17 had rounded ovate shape of leaf whereas Only genotype JS SH-93 37 and JS SH-9305 had lanceolate leaf shapes, and all the remaining lines belonged to the pointed ovate group of leaf shapes.

Pod characters

Considering the pubescence color of soybean, it is regulated by the T and Td loci, exhibiting epistatic effects. Combinations of TT TdTd result in a tawny color, TT tdtd leads to light tawny or near-gray, and ttTdTd or tttdtd results in a gray color (Iwashina et al. 2006). Pod pubescence, often linked to insect resistance, was consistent across multiple locations. In this study, all genotypes, except JS-335, VS-1-17-17, VS-1-28-17, and VS-1-80-17, exhibited pod pubescence. Pubescence color, categorized as grey and brown, was influenced by the T and Td loci, with brown pubescence seen in NRC-37, MACS-1188, AGS 339, HIMSO 1563, and lines VS-4-198-17, VS-4-219-17, VS-4-223-17, and VS-4-227-17. JS SH-93 37, JS SH-9305, NRC-37, VS-5-266-17, and lines derived from MACS-1188 X AGS 449 had brown pod color, while lines VS-4-223-17 and VS-4-244-17 were susceptible to shattering.

Seed characters

Some lines, including GC-8450132-01, VS-1-28-17, VS-1-75-17, JS SH 9337, AGS 459, and VS-4-198-17, exhibited a green seed coat, while AGS-450 and AGS-457 had brown seed color. All lines featured a yellow seed coat. Seed traits, such as size and coat color, can distinguish soybean varieties (Morris and Payne 1977). A study by Duan et al. (2022) highlighted the GmST05 gene's role in controlling seed thickness and size in soybean germplasm. In a study by Zhao et al. (2021), it was revealed that the triplet combination of GmCYP78A57, GmCYP78A70, and GmCYP78A72 genes leads to a notable reduction in seed size. This suggests functional redundancy among these three GmCYP78A genes.

Value added traits

Oil content

In our assessment of genotypes for desirable traits in vegetable soybeans, we conducted a comparative analysis of quality traits at both the green and mature stages, focusing on the oil content in the R6 stage. The observed oil content in this stage ranged from 16.19 to 20.76%, as illustrated in Fig. 2. Notably, the oil content in the green stage was lower than that in the mature stage, with a relatively narrow difference between the two stages, spanning 18.47 to 22.08%. Among the genotypes screened, JS-335 (20.59%), MACS-1037 (20.03%), MACS-1188 (20.11%), NRC-37 (20.42%), HIMSO 1563 (20.01), VS-2-128-17 (20.15%), VS-2-141-17 (20.76%), VS-3-99-17 (20.37%), and VS-4-198-17 (20.08%) were categorized as having high oil content, exceeding 20%. Conversely, the remaining genotypes exhibited an average oil content. The present analysis provides valuable insights into the variation in oil content among different genotypes of vegetable soybeans, highlighting specific genotypes with desirable high oil content for potential consideration in further cultivation or breeding programs.

Protein content

Soybean seeds boast a protein content of 40%, rich in vital amino acids like phenylalanine, valine, tryptophan, threonine, lysine, leucine, and isoleucine, along with essential sulfur-containing amino acids, including methionine and cystine. These components contribute to a well-rounded and nutritious diet (Basson et al. 2021; Molinari et al. 2023). Opting for soy protein over animal protein is considered advantageous for overall health. In our study, protein content was lower in the green stage (18.11–28.92%) compared to the mature stage (27.57–41.39%). Notably, lines VS-4-198-17, VS-4-219-17, and VS-4-238-17 exhibited medium protein content (38.10, 38.43, and 39.18%, respectively), while the remaining three lines had lower protein content**.**

Zinc and iron content

Vegetable soybean is renowned for its delicious taste, and its micronutrients, as indicated by Fine et al. (2014), not only enhance flavor and color but also offer protection against health disorders like cardiovascular diseases and cancer. Zinc is a crucial micronutrient with catalytic functions in over 100 enzymes, impacting human metabolism, DNA transcription, RNA translation, and cellular division. Iron, another essential trace mineral, plays a vital role in energy-related reactions and is a key component of hemoglobin and myoglobin. Iron deficiency can lead to anemia, which is prevalent in Indian women. Iron and zinc deficiencies in resource-poor regions are exacerbated by low mineral bioavailability in staple foods. Vegetable soybeans are beneficial for meeting daily iron and zinc requirements. In the R6 stage, iron content ranged from 3.24 to 7.12 mg, and zinc content ranged

Table 2. The DUS evaluation of soybean genotypes

	Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	JS-335	P	Se	M	Po	Dg	Pu	A	-	Y	M	Y	Ns	E	M	Y
2	JS SH-93 37	P	Se	M	le	G	Pu	P	Gy	Y	M	Br	Ns	E	L	Bl
3	JS SH-9305	P	Se	E	le	Dg	Pu	P	Gy	Y	M	Br	Ns	E	M	Y
4	NRC-37	A	se	M	Po	G	W	P	Br	Y	L	Br	Ns	E	M	Y
5	MACS-1037	A	Se	M	Po	G	W	P	Gy	Y	M	Y	Ns	E	M	Y
6	MACS-1188	A	Se	M	Ro	G	W	P	Br	Y	L	Br	Ns	E	M	Y
7	NRC37	A	Se	M	Po	G	W	P	Br	Y	L	Br	Ns	E	M	Y
8	Swarna Vasundhara	P	Se	M	Ro	G	Pu	P	Gy	Y	L	Y	Ns	E	L	Y
9	GC-8450132-01	P	E	M	Po	G	Pu	P	GY	G	L	Br	Ns	M	M	G
10	AGS-339	P	E	E	Ro	G	Pu	P	Br	Y	S	Br	Ns	E	L	Y
11	AGS-450	P	E	E	Po	G	Pu	P	Gy	Y	S	Br	Ns	E	L	Br
12	AGS-457	A	E	E	Po	G	W	P	Gy	Y	S	Br	Ns	E	L	Br
13	AGS-459	A	E	E	Po	G	W	P	Gy	Y	S	Br	Ns	E	L	Bl
14	HIMSO-1563	A	E	M	Ro	Dg	W	P	Br	G	S	Br	Ns	M	L	G
15	VS-1-17-17	P	Se	E	Ro	G	Pu	A	-	Y	S	Y	Ns	E	L	Y
16	VS-1-28-17	A	Se	E	Po	Dg	W	A	-	Y	S	Y	Ns	E	L	G
17	VS-1-67-17	A	Se	E	Po	G	W	P	Gy	Y	S	Y	Ns	E	L	Y
18	VS-1-75-17	A	Se	M	Po	G	W	P	Gy	Y	S	Y	Ns	E	L	G
19	VS-1-80-17	P	Se	E	Po	G	Pu	A	-	Y	S	Y	Ns	E	L	Y
20	VS-2-128-17	P	Se	M	Po	G	Pu	P	Gy	Y	M	Y	Ns	E	L	Y
21	VS-2-130-17	P	Se	M	Po	G	Pu	p	Gy	Y	S	Y	Ns	E	L	Y
22	VS-2-141-17	P	Se	M	Po	G	Pu	P	Gy	Y	M	Y	Ns	E	L	Y
23	VS-3-99-17	A	Se	M	Po	G	W	P	Gy	Y	S	Y	Ns	E	L	Y
24	VS-3-108-17	P	Se	M	Po	G	Pu	P	Gy	Y	S	Y	Ns	E	L	Y
25	VS-4- 198 -17	A	Se	M	Po	G	W	P	Br	Y	S	Br	Ns	E	L	Bl
26	VS-4-219 -17	A	Se	M	Po	G	W	P	Br	Y	S	Br	Ns	E	L	Y
27	VS-4-223 -17	A	Se	M	Po	G	W	P	Br	Y	S	Br	St	E	L	Y
28	VS-4-227 -17	A	Se	M	Po	G	W	P	Br	Y	S	Y	Ns	E	L	Y
29	VS-4-238 -17	A	Se	E	Po	G	W	P	Gy	Y	S	Br	Ns	E	L	Y
30	VS-4-244 -17	A	Se	M	Po	G	W	P	Gy	Y	S	Y	St	E	L	Y
31	VS-4-245 -17	A	Se	M	Po	G	W	P	Gy	Y	S	Br	Ns	E	L	Y
32	VS-5- 265-17	P	Se	M	Ro	Dg	Pu	P	Gy	Y	M	Y	Ns	E	L	Y
33	VS-5- 266-17	P	Se	M	Ro	Dg	Pu	P	Gy	Y	M	Br	Ns	E	L	Y
34	VS-5- 273 -17	P	Se	M	Ro	Dg	Pu	P	Gy	Y	S	Y	Ns	E	L	Y
35	VS-5- 275 -17	P	Se	M	Ro	G	Pu	P	Gy	Y	M	Y	Ns	E	L	Y

1. Anthocyanin; 2. Plant growth Type; 3. Days to 50% flowering; 4. Leaf shape; 5. Leaf color; 6. Flower color; 7. Pod pubescence; 8. Color of pod pubescence; 9. Seed: Cotyledon color; 10. Plant height;11.Pod color; 12. Pod Shattering; 13.Plant Days to maturity: 14. Seed size; 15.Seed coat color
A = Absent, Bl = Black, Br = Brown, Dg = Dark-green, Dl = Dull, E = Early, El = elliptical, Er = Erect, G = Green, Gy = Grey, L = Large, Lt = Late, Ln = Lanceolate, H= High, AV=Average, M = Medium, Ns = Non-shattering, P = Present, Po = Pointed ovate, Pu = Purple, Ro = Rounded ovate, S = Short, Sd = Semi-determinate, Se = Semi-erect, Sm = Small, Sn = Shiny, Sp = Spherical, St = Shattering, T = Tawny, Tl = Tall, W = White, Y = Yellow, Yg = Yellow-green

from 3.1 to 8 mg/100 g. As soybeans mature, iron increases (4.88–9.79 mg/100 g), while zinc decreases (2.1–7.3 mg/100 g). AGS-450 showed the highest iron content, and Line VS-1-17-17 recorded the highest zinc content, also having the maximum iron content among all lines. Earlier published reports also suggested the significance of soybeans in addressing iron and zinc deficiencies (Akomo et al. 2016; Akande et al. 2016; Agyenim-Boateng et al. 2023).

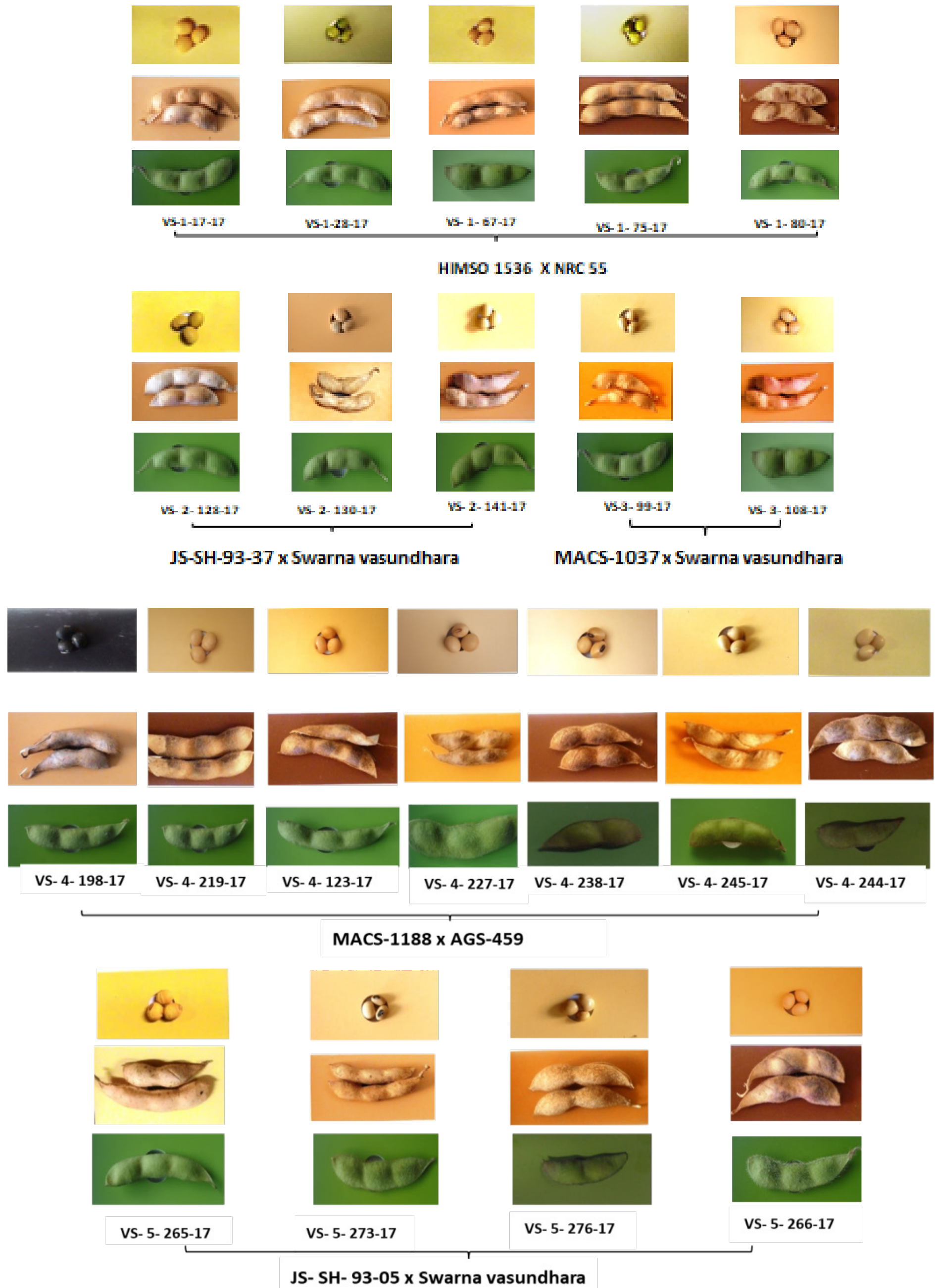

Fig. 1. Variation in pod and seed coat color of vegetable soybean genotypes under study as per The Royal Horticultural Society catalog, London

Carbohydrate content

In the investigation of vegetable-type soybean genotypes, carbohydrate and sugar contents were assessed during the green stage, as presented in Fig. 2. The average carbohydrate content ranged from 7.43 to 23.51 g/100 g. Zhang et al. (2017) reported that carbohydrates are the predominant component, ranging from 42.4 to 48.1%, followed by protein (34.2–35.4%), oil (13.1–17.5%), and ash (4.21–4.88%) for three vegetable soybean varieties grown in Virginia. In the present study, the sugar content ranged from 0.9 to 3.43 g/100 g, surpassing the maximum sugar content of 2.02 g/100 g reported by Kumar et al. (2007) in their analysis of soybean cultivars at the R6 stage.

Sugar content plays a crucial role in the taste of edamame; previous studies by Silva, Carrão-Panizzi et al. (2009) and Santana et al. (2012) suggested that the presence of sucrose, along with other sugars, contributes to the distinctive flavor of edamame.

Trypsin inhibitor content

As proposed by Talukdar et al. (2014), soybean seeds harbor anti-nutritional factors like Kunitz trypsin inhibitor, this factors should be eliminated to ensure the safe utilization

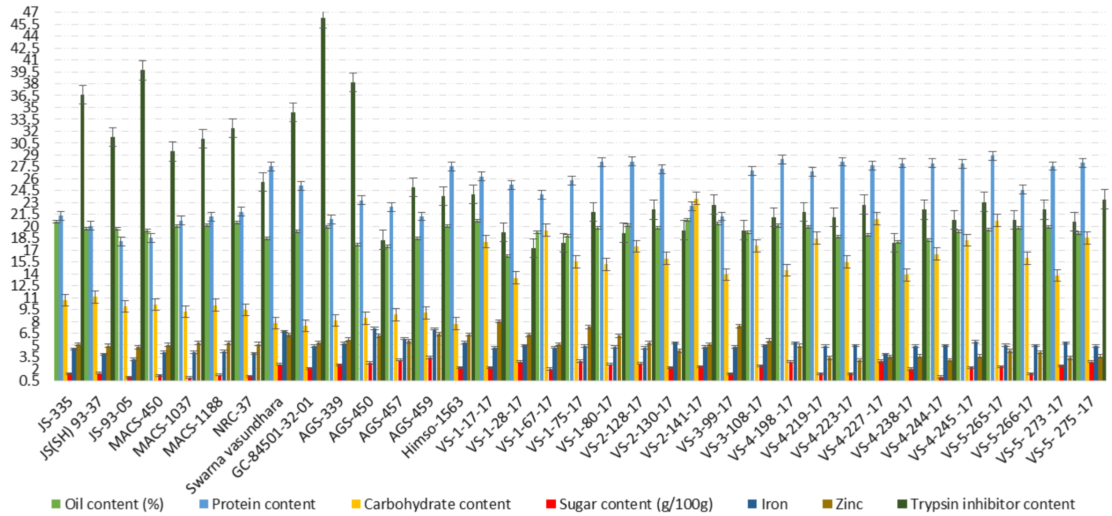

Fig. 2. A comprehensive evaluation of qualitative traits and nutritional composition in vegetable soybean at green stage

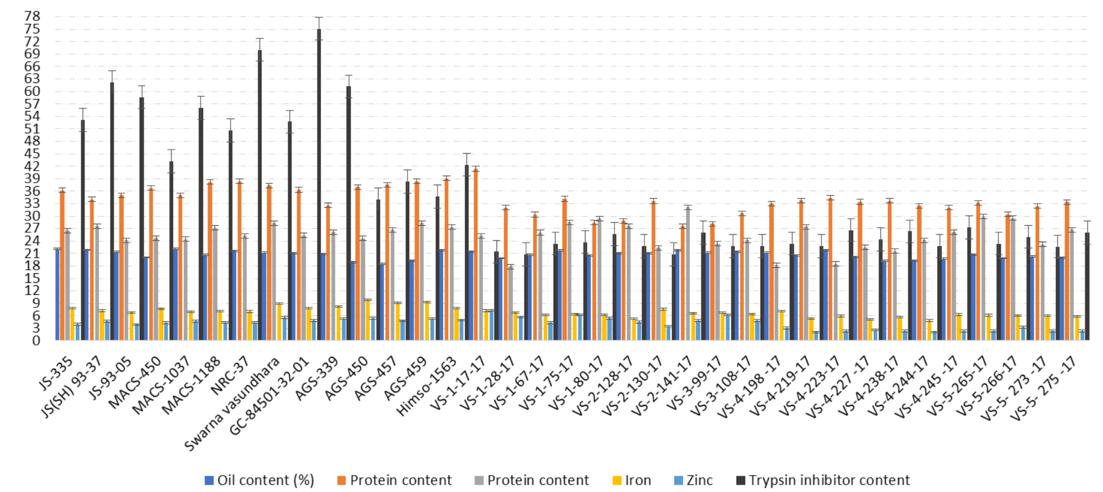

Fig. 3. Comprehensive evaluation of qualitative traits and nutritional composition in vegetable soybean at mature stage

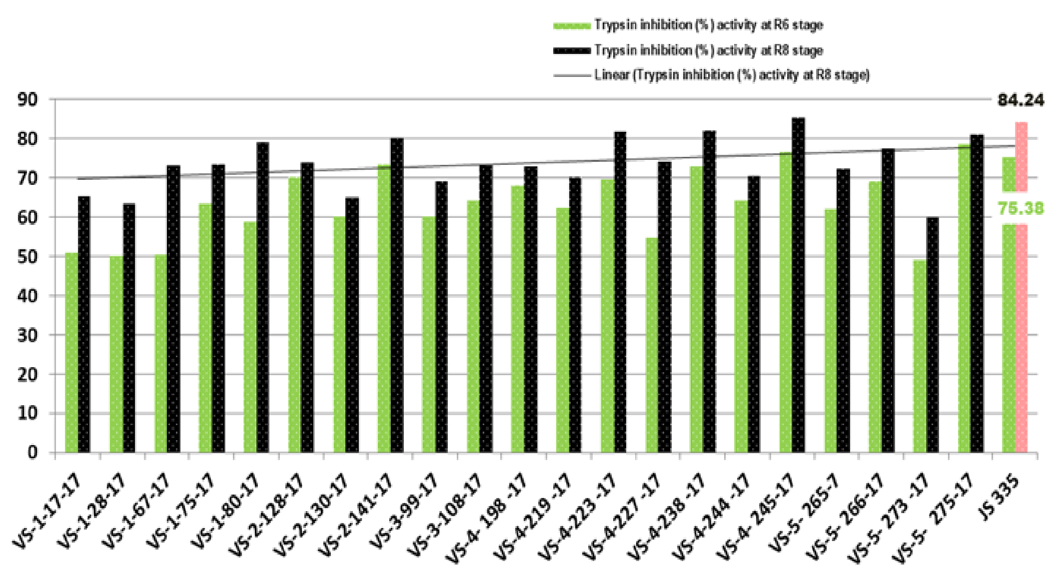

Fig. 4. Trypsin inhibition activity of advanced line at green and mature stage compared with JS-335

Table 3. Sensory scores genotypes for value-added traits

Genotypes	Aroma	Texture	Taste	Overall acceptability
JS-335	4.5 c	3.6 c	3.5 c	3.87 b
JS(SH)93-37	4.6 c	4.2 c	3.7 c	4.17 b
JS-93-05	3.9 c	3.8 c	2.8 c	3.50 b
MACS-450	4.7 c	3.7 c	2.9 c	3.77 b
MACS-1037	4.5 c	4.0 c	3.0 c	3.83 b
MACS-1188	3.8 c	3.9 c	5.3 c	4.33 b
NRC-37	3.7 c	3.5 c	3.3 c	3.50 b
Swarna vasundhara	6.8 a	6.8 a	6.5 a	6.37 a
GC-84501-32-01	6.2 a	5.9 a	6.1 a	6.07 a
AGS-339	6.5 a	6.7 a	6.8 a	6.67 a
AGS-450	6.9 a	6.5 a	7.4 a	6.93 a
AGS-457	6.7 a	6.8 a	6.6 a	6.37 a
AGS-459	6.8 a	6.8 a	6.8 a	6.47 a
Himso-1563	6.3 a	5.2 a	6.4 a	6.30 a
Genotypes	**Aroma**	**Texture**	**Taste**	**Overall acceptance**
VS-1-17-17	3.69 d	5.10 ab	5.14 b	4.93 b
VS-1-28-17	3.48 d	5.14 ab	5.26 b	4.96 b
VS-1-67-17	2.38 d	5.15 ab	5.14 b	4.31 b
VS-1-75-17	2.06 d	6.95 ab	5.15 b	5.69 b
VS-1-80-17	2.19 d	6.56 ab	5.12 b	4.96 b
VS-2-128-17	2.19 d	5.47 b	5.36 b	4.54 b
VS-2-130-17	2.94 d	5.23 b	3.26 b	3.95 b
VS-2-141-17	4.90 d	5.47 b	5.69 b	5.19 b
VS-3-99-17	3.23 d	3.36 b	5.69 b	4.26 b
VS-3-108-17	3.36 d	4.31 b	3.69 b	4.13 b
VS-4-198-17	4.25 d	5.54 c	4.97 b	4.97 b
VS-4-219-17	5.17 d	4.69 c	4.23 b	4.80 b
VS-4-223-17	5.20 d	5.16 c	4.97 b	5.12 b
VS-4-227-17	4.47 d	5.46 c	3.69 b	4.69 b
VS-4-238-17	4.15 d	4.47 c	4.26 b	4.51 b
VS-4-244-17	5.47 d	5.47 c	4.25 b	5.08 b
VS-4-245-17	5.64 d	5.31 c	3.65 b	4.93 b
VS-5- 265-17	5.14 bc	5.23 b	3.87 b	4.84 b
VS-5- 266-17	5.16 bc	5.47 b	3.97 b	4.93 b
VS-5- 273-17	5.78 bc	5.36 b	4.69 b	5.24 b
VS-5- 275-17	5.26 bc	5.47 b	3.26 b	4.78 b

1. Strongly disliked, 2. Moderately disliked, 3. Slightly disliked, 4. Indifferent, 5. Slightly liked, 6. Moderately liked, and 7. Strongly liked

of soybeans for food or feed purposes (Shiva Kumar et al. 2015). The trypsin inhibition content within the selected line varied from 16.25 to 46.26 mg in the green stage and from 20.8 to 75.09 mg in the mature stage. Vegetable soybeans exhibited lower trypsin content than grain soybeans.

Fig. 5. The promised lines identified by Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola

Notably, in the advanced population, these lines have particularly lower trypsin levels than grain-type soybean varieties. Among them, VS-5-273-17 exhibited the lowest trypsin level in the green stage, followed by VS-1-67-17 (50.6%), VS-1-17-17 (50.9%), and VS-4-227-17 (54.9%). In the context of JS-335 being the most popular soybean variety in Maharashtra, most of the lines were found to have a lower trypsin inhibition percentage in the green stage (Fig. 4).

Organoleptic evaluation

Sensory evaluation, crucial for breeding and new food crop development, genotype under this study showed the significant differences for organoleptic traits., highlighted AGS 459 as the top performer in taste, texture, and overall acceptance, closely followed by AGS-457 and AGS-450. Grain soybeans received less favorable feedback. Kumar and coworkers also studied vegetable soybean genotypes in 2011, author scored liking and disliking for the taste by using a nine-point hedonic scale. Among these, 'Dada-cha ma-me' was the highest (8.8) highest scorer and 'Table Variety' and 'AGS439' had the lowest taste score (6.0). Scoring. Scoring varies because of comparison among the vegetable type and vegetable and grain type soybean. In our observation crosses involving HIMSO 1563, NRC 55 produced lines like VS-1-75-17, known for a sweet taste and excellent overall acceptability. In the MACS-1037 AGS 459 cross, VS-3-99-17 and VS-3-108-17 achieved moderate acceptability scores. From the MACS-1188 AGS 459 cross, VS-4-223-17 stood out for taste and aroma, followed by VS-4-244-17 with commendable overall acceptability. Aromatic lines, including VS-5-273-17, were noteworthy for their sweet taste and high overall acceptability, consistent with findings by Tsou and Hong (1991) and Ma et al. (2015).

This study explores the qualitative traits and nutritional composition of vegetable soybeans, emphasizing their richness and delectability. Advanced lines, particularly VS-1-17-17, VS-2-141-17, and VS-5-265-17, outshine traditional grain-type soybeans in appearance (As shown in Fig. 5), as well as nutritional quality, line VS-2-141-17 stands out as a promising candidate, excelling in both nutritional and sensory attributes. Organoleptic assessments identify AGS-459, AGS-457, and AGS-450 as varieties with superior taste, texture, and overall acceptability. These findings provide valuable insights for future cultivation and breeding efforts, contributing to the enhancement of vegetable soybean breeding in India.

Authors' contribution

Conceptualization of research (PJ, SS, PS, DR, RN); Designing of the experiments (PP, PJ, PS, DR); Contribution of experimental materials (PV); Execution of field/lab experiments and data collection (PP, DG, DR, PS); Analysis of data and interpretation (PP); Preparation of the manuscript (PP, PS, DR).

Acknowledgments

We acknowledge the support received from the Head of the Soil Science and Plant Biochemistry Department and the Oilseeds Research Unit, Dr. PDKV, for the excellent facilities provided.

References

Agyenim-Boateng K.G., Zhang S., Zhang S., Khattak A.N., Shaibu A., Abdelghany A.M., Qi J., Azam M., Ma C., Feng Y. and Feng H. 2023. The nutritional composition of the vegetable soybean (Maodou) and its potential in combatting malnutrition. Front. Nutri., **9** : p.1034115. https://doi:10.1007/s00122-023-04396

Akande T., Onyezili F.N. and Ikwebe J. 2018. Biochemical characterization of soybean germplasms with respect to bioavailable iron and zinc, vitamin A, and crude protein. Afr. J. Biochem. Res., **12**(4): 40-44. https://doi.org/10.5897/AJBR2016.0881

Akomo P.O., Egli I., Okoth M.W., Bahwere P., Cercamondi C.I., Zeder C., Njage P.M.K. and Owino V.O. 2016. Estimated iron and zinc bioavailability in soybean-maize-sorghum ready to use foods: Effect of soy protein concentrates and added phytase. J. Food Proc. Technol., **7**(02): 1-5. https://doi.org/10.4172/2157-7110.1000556

Anonymous. 2009. Guidelines for the conduct of test for distinctiveness, uniformity and stability (DUS) on Soybean [*Glycine max* (L.) Merrill]. P. Var J. India, **3**(10): 289–98.

Basson A.R., Ahmed S., Almutairi R., Seo B., Cominelli F. 2021. Regulation of intestinal inflammation by soybean and soy-derived compounds. Foods, **10**: 774https://doi.org/10.3390/foods10040774

Carneiro R., Duncan S., O'Keefe S., Yu D., Huang H., Yin Y., Neill C., Zhang B., Kuhar T., Rideout S. and Reiter M. 2020. Utilizing consumer perception of edamame to guide new variety development. Front. Sustain. Food Syst., **4**: p.556580. https://doi.org/10.3389/fsufs.2020.556580

Carrão-Panizzi M.C., Favoni S.P.D.G. and Kikuchi A. 2002. Extraction time for soybean isoflavone determination. Braz. Arch. Biol. Technol., **45**: 515-518. http://dx.doi.org/10.1590/S1516-89132002000600015

Dhaliwal I., Khosla G., Singh T.P., Gill B.S. and Kaushik P. 2020. DUS characterization of some released varieties and advanced breeding lines of soybean (*Glycine max* L.) under Punjab agroclimatic conditions. AgriRxiv., p.20210198131. https://doi.org/10.31220/agriRxiv.2020.0001

Dubois M., Gilles K.A., Hamilton J.K., Rebers P.A. and Smith F. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem., **28**: 350-356. http://dx.doi.org/10.1021/ac60111a017

Duan Z., Zhang M., Zhang Z., Liang S., Fan L., Yang X., Yuan Y., Pan Y., Zhou G., Liu S. and Tian Z. 2022. Natural allelic variation of GmST05 controlling seed size and quality in soybean. Plant Biotechnol. J., **20**(9): 1807-1818. https://doi.org/10.1111/pbi.13865

Fine F., Brochet C., Gaud M., Carre P., Simon N., Raml F. and Joffre F. 2016. Micronutrients in vegetable oils: The impact of crushing and refining processes on vitamins and antioxidants in sunflower, rapeseed, and soybean oils. European J. Lipid Sci. Technol., **118**(5): 680-697. https://doi.org/10.1002/ejlt.201400400

Gupta., Mahajan V., Khati P. and Srivastva A.K. 2010. Distinctness in Indian soybean (Glycine max) varieties using DUS characters. Indian J. agric. Sci., **80**(12): 1081.

Golicz A. A., Batley J. and Edwards D. 2016. Towards plant pangenomics. Plant. Biotechnol. J., **14**: 1099–1105. https://doi.org/10.1111/pbi.12499

Iwashina T., Benitez E.R. and Takahashi R. 2006. Analysis of flavonoids in pubescence of soybean near-isogenic lines for pubescence color loci. J. Hered., **97**(5): 438-443.https://doi.org/10.1093/jhered/esl027

Kakade M.L., Rackis J.J., McGhee J.E. and Puski G. 1974. Determination of trypsin inhibitor activity of soy products: a collaborative analysis of an improved procedure.

Kumar V., Rani A., Billore S.D. and Chauhan G.S. 2006. Physico-chemical properties of immature pods of Japanese soybean cultivars. Int. J. Food Properties, **9**(1): 51-59. https://doi.org/10.1080/10942910500471727

Kumar V., Rani A., Goyal L., Pratap D., Billore S.D., Chauhan G.S. 2011. Evaluation of vegetable-type soybean for sucrose, taste-related amino acids, and isoflavones contents. Int. J. Food Properties, **14**(5): 1142-51. https://doi.org/10.1080/10942911003592761

Lu W., Sui M, Zhao X., Jia H, Han D., Yan X. and Han Y. 2022. Genome-wide identification of candidate genes underlying soluble sugar content in vegetable soybean (*Glycine max* L.) via association and expression analysis. Front. Plant Sci., **13**: 930639. https://doi.org/10.3389/fpls.2022.930639

Ma L., Li B., Han F., Yan S., Wang L. and Sun J. 2015. Evaluation of the chemical quality traits of soybean seeds, as related to sensory attributes of soymilk. Food Chem., **173**: 694-701. https://doi.org/10.1016/j.foodchem.2014.10.096

Masuda R. 2004. The strategy for sweetness increase of vegetable soybeans: maltose, another sugar in boiled seeds. In Proceedings VII World Soybean Research Conference, IV International Soybean Processing and Utilization Conference, III CongressoBrasileiro de Soja (Brazilian Soybean Congress), Foz do Iguassu, PR, Brazil, 29 February-5 March, 2004 (pp. 839-844). Brazilian Agricultural Research Corporation, National Soybean Research Center.

Morris L.F. and Payne R.C. 1977. Phenotypic characteristics of 116 soybean varieties. News Letter Association of Official Seed Analysts.

Molinari M.D.C., Fuganti-Pagliarini R., Yu Y., Florentino L.H., Mertz-Henning L.M., Lima R.N., Bittencourt D.M.D.C., Freire M.O. and Rech E. 2023. Exploring the proteomic profile of soybean bran: Unlocking the potential for improving protein quality and quantity. Plants, **12**(14): 2704. https://doi.org/10.3390/plants12142704

Palmer R.G., Pfeiffer T.W., Buss G.R. and Kilen T.C. 2004. Qualitative genetics. Soybeans: Imp. Prod. Uses., **16**: 137-233. https://doi.org/10.2134/agronmonogr16.3ed.c5

Pardeshi P., Jadhav P., Sakhare S., Zunjare R., Rathod D., Sonkamble P., Saroj R. and Varghese P. 2023. Morphological and microsatellite marker-based characterization and diversity analysis of novel vegetable soybean [*Glycine max* (L.) Merrill]. Mol. Bio. Rep., **50**(5): 4049-4060. https: //doi.org/10.1007/s11033- 023- 08328

Pardeshi P.P., Gangtire D.R., Jadhav P.V., Rathod D.R., Sonkamble P.A., Sakhare S.B., Varghese P. and Nandanwar R.S. 2024. Assessment of genetic diversity of vegetable soybean [*Glycine max* (L.) Merrill] in R6 and R8 stages. Indian. J. Genet. Plant Breed., **84**(02): 250-257.https://doi.org/10.31742/ISGPB.84.2.13

Ramteke R. and Husain S.M. 2008. Evaluation of soybean (Glycine max) varieties for stability of yield and its components. Indian J. agric. Sci., **78**(7): 625.

Raut V.M. 2003. Qualitative Genetics of Soyabean-a review. Soybean Res., **1**: 1-28.

Santana A.C., Carrão-Panizzi M.C., Mandarino, J.M.G., Leite R.S., Silva J.B.D. and Ida E.I. 2012. Effect of harvest at different times of day on the physical and chemical characteristics of vegetable-type soybean. J. Food Technol., **32**: 351-356. https://doi.org/10.1590/S0101-20612012005000044

Shivakumar M., Verma K., Talukdar A., Srivastava N., Lal S.K., Sapra R.L. and Singh K.P. 2015. Genetic variability and effect of heat treatment on trypsin inhibitor content in soybean [*Glycine max* (L.) Merrill.]. Legume Res., **38**(1): 60-65. DOI: https://doi.org/10.5958/0976-0571.2015.00010.7

Shomura A., Izawa T., Ebana K., Ebitani T., Kanegae H., Konishi S. and Yano M. 2008. Deletion in a gene associated with grain size increased yields during rice domestication. Nat. Genet., **40**(8): 1023-1028.https://doi.org/10.1038/ng.169

Silvertown J.W. 1981. Seed size, life span, and germination date as coadapted features of plant life history. The American Naturalist, **118**(6): 860-864.

Song J.Y., An G.H. and Kim C.J. 2003. Color, texture, nutrient contents, and sensory values of vegetable soybeans [*Glycine max* (L.) Merrill] as affected by blanching. Food Chem., **83**(1): 69-74. https://doi.org/10.1016/S0308-8146(03)00049-9

Sood B.C. and Siddiq E.A. 1978. Indian J. Genet. Plant Breed., **38**: 268-271. Takahashi R., Matsumura H., Oyoo M.E. and Khan N.A. 2008. Genetic and linkage analysis of purple–blue flower in soybean. J. Hered., **99**(6): 593-597.https://doi.org/10.1093/jhered/esn041

Takahashi R., Matsumura H., Oyoo M.E. and Khan N.A. 2008. Genetic and linkage analysis of purple–blue flower in soybean. J. Hered., **99**(6): 593-7. https://doi.org/10.1093/jhered/esn041

Talukdar A., Shivakumar M., Verma K., Kumar A., Mukherjee K. and Lal S.K. 2014. Genetic elimination of Kunitz trypsin inhibitors (KTI) from DS9712, an Indian soybean variety. Indian. J. Genet. Plant Breed., **74**(Suppl.) pp. 608-611. https://doi.org/10.5958/0975-6906.2014.00898.0

Tsou S.C.S. and Hong T.L. 1991. Research on vegetable soybean quality in Taiwan. In Vegetable soybean research needs for production and quality improvement. Proceedings of a workshop held at Kenting, Taiwan. Vol. **29**: 103-7.

Varshney R. K., Sinha P., Singh V. K., Kumar A., Zhang Q. and Bennetzen J. L. 2020. 5Gs for crop genetic improvement. Curr. Opin. Plant Biol., **56**: 190–196. https://doi.org/10.1016/j.pbi.2019.12.004

Wolfe E., Popp M., Bazzani C., Nayga R.M., Danforth D., Popp J., Chen P. and Seo H.S., 2018. Consumers' willingness to pay for edamame with a genetically modified label. Agribusiness, **34**(2): 283-299. https://doi.org/10.1002/agr.21505

Zhang B., Lord N., Kuhar T., Duncan S., Huang H., Ross J., Rideout S., Arancibia R., Reiter M., Li S. and Chen P. 2022. 'VT Sweet': A vegetable soybean cultivar for commercial edamame production in the mid-Atlantic USA. J. Plant Regist, **16**(1): 29-33.https://doi.org/10.1002/plr2.20140

Zhang Q., Gao Q., Herbert S. J., Li Y., Hashemi A.M. 2010. Influence of sowing date on phenological stages, seed growth and marketable yield of four vegetable soybean cultivars in North-eastern USA. Afr. J. Agric. Res., **5**(18): 2556-62.

Zhang Q., Li Y., Chin K.L. and Qi Y. 2017. Vegetable soybean: Seed composition and production research. Ital. J. Agron., **12**(3): https://doi.org/10.4081/ija.2017.872

Zhao X., Muhammad N., Zhao Z., Yin K., Liu Z., Wang L., Luo, Z., Wang L. and Liu M. 2021. Molecular regulation of fruit size in horticultural plants: A review. Scientia Horticulturae, **288**: p.110353.https://doi.org/10.1016/j.scienta.2021.110353