SKUAST Journal of Research 25(3): 376-386; (2023)
(*DOI No: 10.5958/2349-297X.2023.00051.X*); NAAS rating: 4.17

Review Paper

Vegetable soybean (*Edamame*): a potential area of research - a review

Moinuddin, *Farooq A. Khan[1], Mohammad Amir[2], Sumati Narayan[3],
Zaffar Mahdi Dar[1] and [4]Mohammad Hussain Khan

Department of Agriculture, SGRR University, Dehradun, Uttarakhand; [1]Division of Basic Sciences and Humanities; [3]Division of Vegetable Science, Faculty of Horticulture, SKUAST-K, Shalimar; [2]Department of Agriculture, LPU, Phagwara, Punjab; [2]Department of Horticulture, Uttarakhand
e-mail: drkhan_387@skuastkashmir.ac.in*

(Received May 19, 2023; accepted July 01, 2023)

ABSTRACT

Nutritional and economic insecurity lead to chronic diseases and constitute a major challenge for the increasing population on the earth. Introduction of new vegetables and legumes is one of the important efforts to provide nutritional diets such as proteins, carbohydrates, vitamins and essential minerals. *Edamame* is a type of soybean [*Glycine max* L. (Merr.)] used as green vegetable that is harvested when seeds are fully developed but still bright green (R6 physiological stage) in contrast to traditionally grown grain soybean harvested at dry-mature (R8 stage) stage. Vegetable soybean is used for direct human consumption in food dishes, such as soups, stews, and boiled or -salted snacks; in consequence, sensorial attributes of vegetable soybean are essential for the marketability of the product and must be considered in a vegetable soybean breeding program. Vegetable soybean mainly differ from grain soybean in respect of their large sized seed with higher level of sugars (3.0%), protein (11.4%), minerals (calcium-70 mg/ 100 g, potassium-140 mg/ 100 g and phosphorus-140 mg/100 g), vitamins (carotene 100 mg/100 g, ascorbic acid-27 mg/100 g and alpha tocopherol-12 µg/seed). *Edamame* also has more seed, grey pubescence, bright green pod and seed coat color. However, the cultivation of *edamame* is still not popular in our country particularly due to unawareness, availability of specific varieties for different climatic conditions, issue of seed germination and relatively large crop duration. The present article emphasizes the attention of the scientist for development of suitable *edamame* varieties, improved cultivation techniques and other scientific interventions in order to reduce the nutritional insecurity.

Keywords: *Edamame*, minerals, nutritional security, protein, R6 stage, sugar

Food insecurity is a worldwide problem and the number of undernourished people in the world increased from 783.7 million to 828.0 million between 2014 and 2021 (FAO, 2022). Soybean (*Glycine max* L. Merril) is the world's most important seed legume whose seed is used as a source of edible oil and protein for both human and livestock consumption and for various industrial purposes. It is one of the richest and cheapest sources of protein and is a staple in the diets of people and animals in numerous parts of the world. Soybean seeds contain about 35-50% proteins and 18-24% oils, depending of the variety and growing conditions. However, in addition to its uses as seed grain, green pods of soybean are also being used as vegetable. It also helps to build up the soil fertility by fixing large amount of atmospheric nitrogen through the root nodules (Yoshiki *et al*., 2013; Elhady *et al*., 2020) and also through leaf fall on the ground at maturity (Singh, 1983; Smith, 1992) that significantly reduced the cost of nitrogenous fertilizers. It contributes to 25 % of the global edible oil and also provides vegetable protein for millions of people. India produces 13.15 million tonnes of soybean from an area of 11.67 million hectares and the production share accounts 42% of country's total oil seeds production (Reddy *et al*., 2019). Hence, soybeans have become a top choice for protein and as such, they are strategically traded around the world.

Edamame: Based on the end uses, there are three general groups of soybeans (i) commercial grain (for oil and source of protein in animal feeds), (ii) forage, and (iii) vegetable (Morse and Carter 1952). The Vegetable soybeans [*Glycine max* (L.) Merr, Fabaceae], also called as *edamame* are similar to its grain counterpart (grain soybean) however, harvested earlier, when pods are bright green (Kambhampati *et al.*, 2021; Figure 1). Vegetable-type soybeans refers to certain large-seeded soybean varieties which are harvested at the green stage for use as a vegetable. The beans can be cooked and served in or out of the pods. *Edamame* is the Japanese term for green vegetable soybeans cooked and served with pods, often as a snack - like peanuts in the shell. The green beans are popped out of the pods directly into the mouth of the person eating them (Shurtleff and Aoyagi, 2001; Shurtleff, and Lumpkin. 2001). The vegetable soybean (or *edamame*) account for about 2% of world soybean production. The seeds of vegetable soybean are larger (>250mg/seed or >30g/100 seeds dry weight) than grain soybean (Carson, 2010), sweeter and more tender than grain soybean (Shanmugasundaram and Yan, 2010). Because of these key differences, grain soybean varieties cannot be directly used for *edamame* production and optimization of additional traits are needed to produce new *edamame* varieties that are better accepted by the producers and the consumers. The green pods of vegetable soybeans are harvested when the seeds fill 80 to 90% of the pod width. This stage corresponds to the R6 stage (full-size seed in top four nodes) of soybean development (Fehr *et al*. 1971) (Fig 1.) whereas grain seed soybean are harvested after full maturity at R8 stage ((full maturity, 95% of pods on the plant are mature). It also varies from the grain soybeans in regard of their dim pubescence, splendid green pod and seed coat colour tone. Vegetable soybean has been reported to be better tasting and suitable for human consumption than grain soybean (Weber 1956).

Present status: At present, the production and consumption of vegetable soybeans are mainly in East and Southeast Asia, with Japan as the largest importing country that dictates the global market. However, interest and trend in cultivation of this crop in other regions has increased significantly. Lack of germplasm or suitable varieties is a major constraint in vegetable soybean production and expansion in the countries outside East and Southeast Asia. Most of the vegetable soybean varieties are genetically related and are susceptible to biotic and abiotic stresses. Extensive research and breeding of vegetable soybeans are still restricted in a few countries such as China, Japan, Taiwan and the USA. The need for focused research and development activities with concern for the environment, farmers' and processors' profit, consumers' preference, quality, and nutrition are needed. Recently, few *edamame* varieties have also been bred by the Indian Council of Agricultural Research of India.

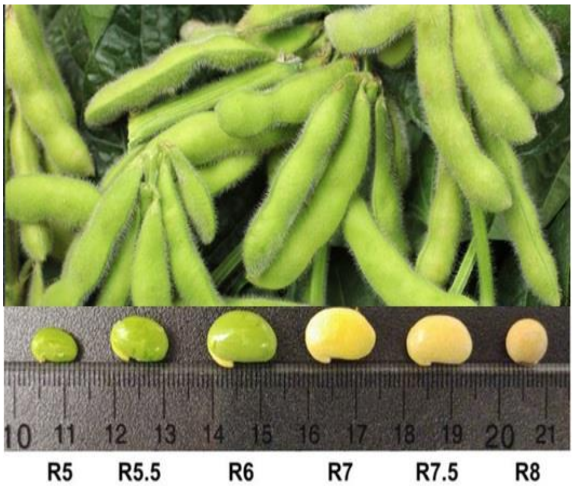


Fig. 1: Vegetable Soybean (*edamame*) at harvest and different seed developmental stages from R5 (seed filling stage) to R8 (maturity) (Kambhampati *et al.*, 2021)

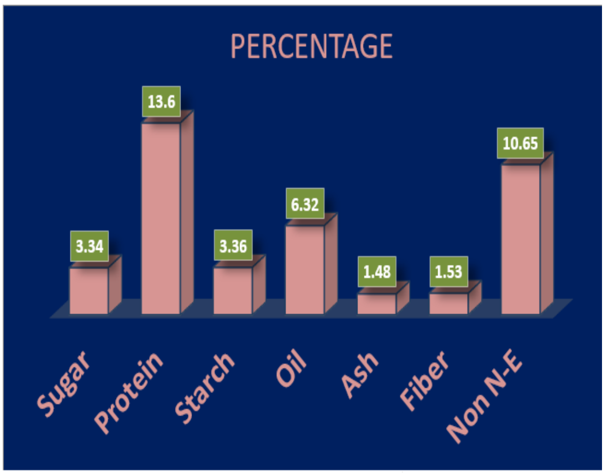


Fig. 2: Nutritive value of vegetable soybean (Chadha and Oluoch, 2004)

Global demand for *edamame* is on the rise. The crop grown and consumed in East Asian countries for centuries, in recent decades *edamame* has been consumed with a rising trend in other parts of the world. *Edamame* is recognized as a healthy plant-based protein which is also rich in vitamins, dietary fiber, and isoflavones. Most commonly, vegetable soybean (*edamame*) is cooked and served in pods as a snack like peanuts or added to salads, soups, stews, or dips (Shurtleff, 2001). Vegetable soybean is a specialty soybean. Green pods with physiologically mature beans are harvested, and whole pods or shelled beans are used as a fresh or frozen vegetable. Vegetable soybeans are prepared in diverse ways, and they are highly nutritious, with excellent taste properties. Unlike grain soybeans, it is perishable.

Nutritional profile: *Edamame* is highly nutritious and rich in phytochemicals beneficial to the human being (Masuda, 1991) and is therefore, considered a nutraceutical or a functional food crop (Messina, 2001). Fresh vegetable soybean is delicious and nutritious, and is an excellent source of protein that can help to alleviate protein malnutrition among children (Fig. 2). Proximate analysis of seed nutritional composition indicated that vegetable soybean has superior nutritional content than green peas (Johnson *et al.*, 1999; Masuda, 1991). Studies also indicated that vegetable soybean is more nutritious (Table 1 & Fig. 3a and b) than many other beans and peas (Longvah *et al.*, 2017; Reddy *et al.*, 2019).

Table 1. Nutrient's content of *edamame* as compared to other legumes vegetable and grain soybeans per 100 g

Products / **Nutrients**	*Edamame* (Raw)	Snap beans (Raw pod)	Green peas	Soybean (Matured)	*Edamame* (Dry)	Soybean (Dry)
Energy (kcal)	135	43	93	417	477	475.38
Water	71.7	86.6	76.5	12.5	0	0
Protein	11.7	2.9	6.9	35.3	41.3	40.24
Lipid	6.2	0.1	0.4	19	21.9	21.66
Carbohydrate	8.8	9.9	15.3	28.2	31	32.15
Ash	1.6	0.5	0.9	5	5.65	5.7
Minerals						
Sodium	1	1	1	1	3.53	1.14
Potassium	590	160	340	1900	2083	2166
Calcium	58	32	23	240	205	273.6
Magnesium	62	21	37	220	219	250.8
Phosphorus	170	62	120	580	600	661.2
Iron	2.7	0.6	1.7	9.4	9.53	10.72
Zinc	1.4	0.4	1.2	3.2	4.94	3.65
Copper	0.41	0.08	0.19	0.98	1.45	1.12
Manganese	0.71	0.22	0.48	1.9	2.51	2.17
Vitamins						
Vitamin A	22	34	35	1	77.7	1.14
Vitamin E	0.8	0.4	0.1	1.8	2.82	2.05
Vitamin K	30	33	27	18	106	20.52
Vitamin B1	0.31	0.13	0.39	0.83	1.09	0.95
Vitamin B2	0.15	0.09	0.16	0.3	0.53	0.34
Niacin	1.6	0.7	2.7	2.2	5.65	2.51
Vitamin B6	0.15	0.09	0.15	0.53	0.53	0.60
Vitamin B12	0	0	0	0	0	0
Folic acid	320	53	76	230	1130	262.2
Pantotenic acid	0.53	0.22	0.63	1.52	1.87	1.73
Vitamin C	27	43	19	Tr.**	95.3	0

*Retinol equivalent; Tr** Trace amount; *** Dry weight base. Source: Takahashi and Ohyama (2011). Djanta *et al*. 2020

Incorporation of vegetable soybean into Indian diets would increase iron (Fe) and zinc (Zn) intake that reduce the disorders related to Fe and Zn deficiency in human beings. The major chemical compounds related to soybean seed taste are sucrose, glutamic acid and alanine (Masuda, 1991; Li *et al*., 2012). Isoflavones is a powerful antioxidant that can reduce the incidence of certain cancer and cardiovascular disease. Vegetable soybeans contain about 50 percent more isoflavones than mature soybean seeds (Koes *et al*., 2005; Wu *et al*., 2004). The calorific value (energy) of vegetable soybean is about 6 times higher than that of green peas. Also, it contains 60% more calcium, and twice the amount of phosphorous and potassium than green peas while as having similar quantities of iron, vitamins B_1 and B_2. It is a rich in ascorbic acid but low in niacin (Masuda, 1991; Zhang and Kyei-Boahen, 2007). However, taste-tests have shown that South Asians generally dislike the "beany" taste of vegetable soybean. To create a variety more favorable to Indians, the World Vegetable Center is working on cultivating a variety that has a more "basmati" (like the fragrant rice) flavor, so that it might be more marketable and beget its nutritional benefits to the Indian population.

As with meat and dairy products, it provides all the essential amino acids that people need and that the body cannot produce itself. It also provides omega-3 alpha-linolenic acid and antioxidant **is oflavones that is helpful in** lowering the risk of cancer and osteoporosis. Comparatively speaking, *edamame* is grown on a much smaller scale but has greater market and nutrition values than general-purpose soybean (Liu, 1999). A comparative analysis of nutritional value of various soy products presented in table 2 indicate that edamame is more nutritious than other products of soybean.

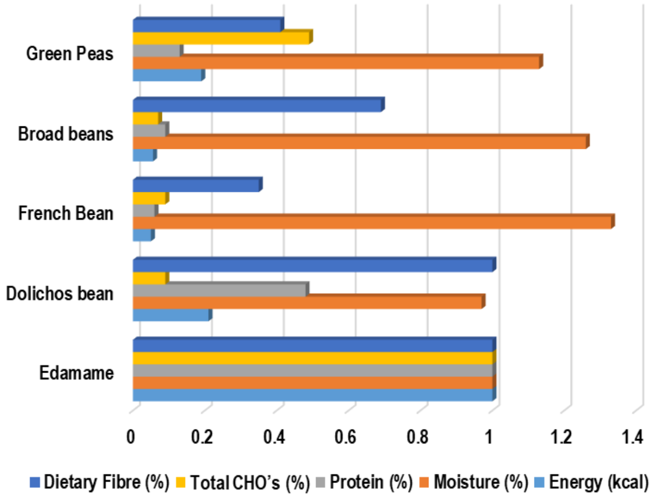


Fig 3a: Nutrient composition of edamame (vegetable soybean) and other vegetables (?? Same caption)

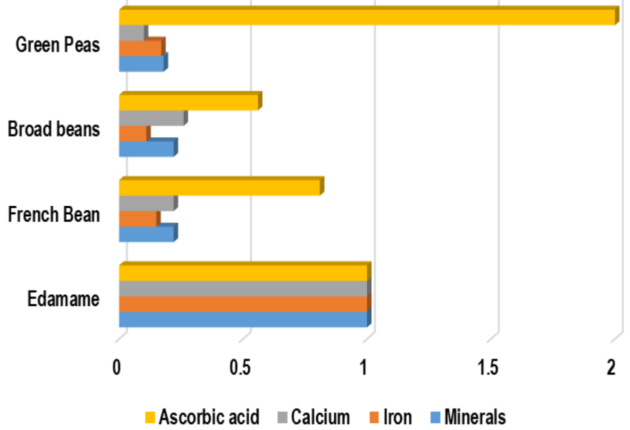


Fig 3b: Nutrient composition of edamame (vegetable soybean) and other vegetable

Agronomic benefits and Market: The farmers, particularly organic vegetable producers will have another vegetable crop to choose to extend crop rotations, supplement farm income, and spread risk. As a legume crop, vegetable soybean is a low input, soil enriching crop that could help farmer minimize insect and disease build-up as well. However, lack of awareness, limited consumer base and dearth of suitable cultivars are some of the factors that limit vegetable soybean production. Currently, *edamame* cultivars that produce high pod yields and also high amount of biomass are being developed through breeding at the Asian Vegetable Research and Development Center, Taiwan. These cultivars serve dual purposes of pod production and as a green manure crop to replenish soil nutrient levels including nitrogen, soil organic matter and improve soil structure and sustainability (Shanmugasundaram, 2001). Short duration *edamame* (99 to 120 d for MG V-VII) also fit well into existing crop rotation patterns.

Vegetable soybeans grown in India would ideally be used as a local fresh crop for domestic consumption so that the Indian population gets the nutritional benefits. As a crop suited to hand-harvest in small production areas, it would be suited to small-hold farmers in India either looking to feed a family or earn an income (Chadha and Oluoch, 2004; Esler, 2011). If one assumes a 5 kg consumption per capita per year in only 20% of the Indian population, it would create a demand of over one million tons of vegetable soybean (Esler, 2011). Vegetable soybean could also become an export cash crop to Japan or, increasingly, the U.S. and Europe (Keatinge *et. al*. 2011). Promotion in different areas of Indian culture, then, would be advantageous for farmers in creating more demand for the crop.

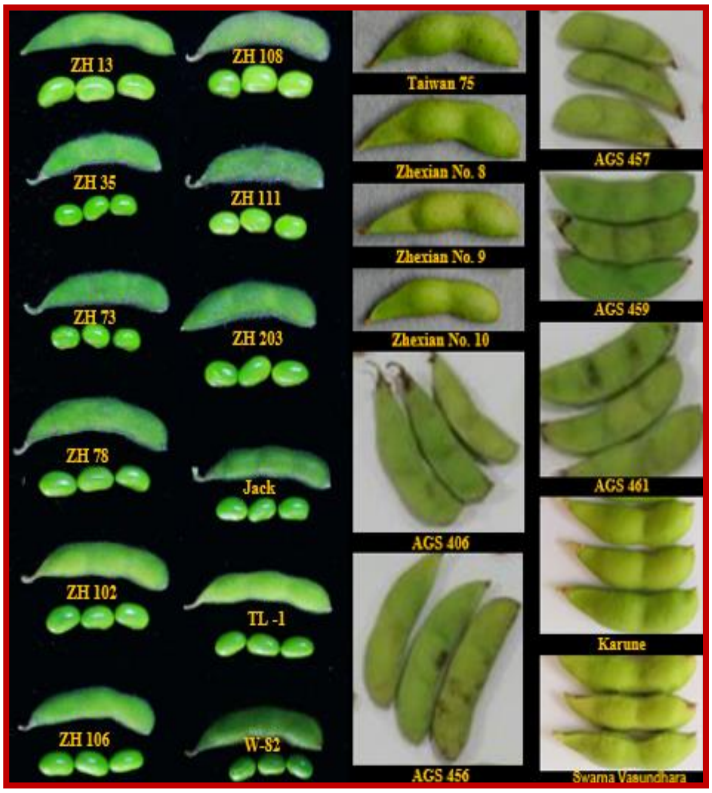
Table 2. A comparison of the nutrient content of various soybean-derived products

Ingredients	*Edamame*	Soybeans	Soy milk	Soy yogurt	Tempeh	Tofu
			per 100-gram portion			
Calories	121	172	43	94	195	144
Protein	12 g	18 g	3 g	4 g	20 g	17 g
Fat	5 g	9 g	1 g	2 g	11 g	9 g
Carbs	9 g	8 g	5 g	16 g	8 g	3 g
Sugar	2 g	3 g	4 g	1 g	–	–
Fiber	5 g	6 g	< 1 g	< 1 g	–	2 g
			percent of the daily value (DV)			
Calcium	5	8	9	9	7	53
Iron	13	29	2	6	12	15
Magnesium	15	20	4	10	18	14
Phosphorus	14	20	3	3	20	15
Potassium	9	11	3	1	9	5
Zinc	12	10	2	3	14	14
Copper	38	45	18	8	60	42
Manganese	45	36	–	–	56	51
Selenium	1	13	4	24	0	32
Thiamine	17	13	2	3	5	13
Riboflavin	12	22	14	2	27	8
Vitamin B6	6	14	2	1	12	5
Folate	78	14	2	2	5	7

Note: A hyphen in the table indicates that data for this nutrient is unavailable

(Masuda, 1991; Kamle *et al*., 2017; Anonymous. 2019)

Breeding methods and achievements: Improved varieties crop varieties are pre-requisite for achieving higher productivity and quality of any crop. Crop breeding is an important tool for enhanced productivity and nutritional quality of the produce for promoting global food security. Being a nutritious food source protein, isoflavones, and vitamins (Mentreddy *et al*., 2002; Lee *et al*., 2018; Mahoussi *et al*., 2020), vegetable soybean (*edamame*) has become a popular food ingredient in many countries (Williams II *et al*., 2022). It has been cultivated in East Asian countries for more than 2,000 years and documented *edamame* varieties have been mainly originated from this area (William and Aoyagi, 2009). Production and breeding of locally adapted *edamame* varieties have also been reported from different parts of the world including North and South America, Europe, and Africa (Konovsky *et al*., 1994) and India (Nair *et al*., 2023) (Fig. 4 and Table 3).



Development of improved soybean cultivars for vegetable offers potential for expanding the domestic and international *edamame* market (Shurtliff and Aoyagi 1991; Lumpkin *et al*. 1992; Shanmugasundaram 1996) and thus the nutritional and economic security of the people.

Table 3. A brief description of the vegetable soybean varieties bred around the world including India

Name of variety/ genotypes	Brief description	Reference
Taiwan 75	Intermediate maturity with growing duration of 84 days, salt susceptible, fairly abundant flavour, plant height 40cm, flower color – white, pod length, 6.0cm, pod width 1.4cm, 100-seed weight 83.0g, sugar content 3.1g/100g.	Ghassemi-Golezani *et al*., 2009; Yu *et al*., 2022
Zhexiandou No. 8	Intermediate maturity with growing duration of 85 days, salt susceptible, fairly abundant flavour, plant height 36cm, flower color – white, pod length, 6.1cm, pod width 1.4cm, 100-seed weight 85.0g, sugar content 2.8g/100g.	Ghassemi-Golezani *et al*., 2009; Yu *et al*., 2022
Zhexian No. 9	Intermediate maturity with growing duration of 85 days, salt susceptible, fairly abundant flavour, plant height 35cm, flower color – white, pod length, 6.4cm, pod width 1.4cm, 100-seed weight 88.0g, sugar content 2.9g/100g.	Ghassemi-Golezani *et al*., 2009; Yu *et al*., 2022
Zhexian No. 10	Intermediate maturity with growing duration of 85 days, salt susceptible, fairly abundant flavour, plant height 44cm, flower color – white, pod length, 5.9cm, pod width 1.4cm, 100-seed weight 80.0g, sugar content 2.6g/100g.	Ghassemi-Golezani *et al*., 2009; Yu *et al*., 2022
AGS 406	The one non-basmati variety. Parentage: Neu Ta Pien 2 x {[(Vesoy 2 x PI 6302) x D62-7812] x KS1}, purple flower and grey seed coat. Notable for lack of pubescence and resulting resistance to pod borer pest. Harvest yield was high and pods were ready for harvest at one time. Earliest variety to flower but not to pod.	Esler, I. 2011; Poornima *et al*., 2014
AGS 456	Basmati variety. Parentage: Dada Cha 2000* x (Taisho Shiroge x Neu Ta Pien 1). Purple or white flower, brown seed coat.	Esler, I. 2011; Poornima *et al*., 2014
AGS 457	Basmati variety. Parentage: Dada Cha 2000 x [Dada Cha 2000 x (Taisho Shiorge x Neu Ta Pien 1)]. White flower and brown seed coat.	Esler, I. 2011; Poornima *et al*., 2014
AGS 459	Basmati variety. Parentage: Dada Cha 2000 x KS 7. White flower and black seed coat. Harvest yield was low.	Esler, I. 2011; Poornima *et al*., 2014
AGS 461	Basmati variety. Parentage: Dada Cha 2000 x KS7. White flower and brown seed coat.	Esler, I. 2011; Poornima *et al*., 2014
Karune	Developed by AICRP on soybean, Bangalore. Popular vegetable soybean in Karnataka (India), plant height 35-42.0cm, bold seeded, days to flower 30-38, protein 16-17.5%, green pod (R6) can be harvested within 70-80days, days to maturity 90-110, green pod yield 1304.00/ 3614kg/ha, oil content 21%, 100 Green Seed Weight at picking 70-75g	Belagali and Kulkarni, 2016; AICRP, 2023
Swarna Vasundhara	Developed by AICRP on soybean, Ranchi. The green pods become ready for the first harvest in 70 to 75 days after sowing with 50% to 55% recovery of shelled bright green beans. There are three pickings in crop duration of 80 to 85 days.	Pan *et al*., 2004; Ravishankar *et al*., 2016; Patil *et al*., 2021
Hara Soya	Days to flowering 32, Days to maturity90, Plant height (43cm) Green seed test weight (36g) Green pod yield -7950kg ha)	Singh *et al*., 2021; AICRP, 2023
NRC 105	Progeny of GC99009-25-9-13GC95024-2-1x R75, Days to flowering- 31, Days to maturity- 86, Plant height (30.0cm) Green seed test weight (70g), Green pod yield 4502kg ha.	AICRP, 2023; Dunna et al., 2023

In addition to above, there are several other varieties/genotypes of *edamame* available in the literature but detailed information about them is not available.

Sanyuewang, Wuyuewu, Wuyueba, Baishuiou, Liuyueba, Baimaoliuyuewang, Daqingdou, Jiangyoudou, Misono Green, Bukers Favorite, White Lion, Sayamusume, Butterbeans, Lucky Lion, Shironomai, Kegon, Gion, Bellesoy, Besweet 2020, Envy, Green Lion 01, Garden Soy 11, Garden Soy 21, Garden Soy 22, Garden Soy 24, Garden Soy 31, Garden Soy 41, Garden Soy 42, IA2025, Midori Giant, Mojo Green, Moon Cake, WSU-618, WSU-706, WSU-710A, WSU-729, WSU-730A, WSU-743, AGS 292, AGS 292, AGS 292, AGS 292, AGS 292, AGS 292, AGS 292, AGS 292, AGS 292, AGS 292, AGS 329, AGS 338, AGS 339, AGS 406, AGS 447, AGS 456, AGS 457, AGS 458, AGS 459, AGS 460, AGS 461, AGS 610, GC 84501- 32-1, Harit Soya, *etc.*

Early maturing summer varieties generally are rated lower in taste than later maturing autumn varieties (Kokobun, 1991) but they are a useful fit for a narrow crop window or to supplement other crops. Variety Kaohsiung No. 1, the AVRDC-developed variety widely introduced in Asia, has been reported to be low in flavor, perhaps due to the lack of the isozyme lipoxygenase, an iron-containing enzyme responsible for different functions in plants like growth and development (Tsou, 1991).

A vast genetic diversity and genomic resources Song *et al*., 2013; Liu *et al*., 2020) can be exploited for *edamame* breeding to improve harvest efficiency and quality through phenotyping. High throughput phenotyping in soybean have been used to study leaf shape (Chen and Nelson, 2004), root architecture (Fenta *et al*., 2014), and canopy cover (Xavier *et al*., 2017). Dhakal *et al*. (2021) develop a phenotyping pipeline to collect images for *edamame* at harvest stage of R6 (full-size seed in top four nodes) to R7 and to quantify major shoot architecture traits related to harvest efficiency including plant height, branching patterns, pod numbers and pod locations. Using known genetic markers and genes that are associated with pod numbers, they found several novel candidate/putative genes that might be related to the pod numbers.

ICAR Research Complex for Eastern Region, Farming System Research Centre for Hill and Plateau Region, Plandu, Ranchi, Jharkhand has developed an improved variety of vegetable soybean, Swarna Vasundhara (Fig. 5) and released by the CVRC for commercial cultivation in India (Pan *et al*., 2004). The green pods become ready for the first harvest in 70 to 75 days after sowing with 50% to 55% recovery of shelled bright green beans. There are three pickings in crop duration of 80 to 85 days. It is an excellent source of digestible proteins, carbohydrates, lipids, essential fatty acids, phosphorus, iron, calcium, zinc, thiamine, riboflavin, Vitamin - E, dietary fiber and sugar. The shelled green beans are used as tasty cooked vegetables and the mature dry seeds are used for making value-added products. Owing to the high nutritional value, the variety was introduced in Jharkhand and other states of India to provide nutritional and livelihood security among the farmers.

All *edamame*, except the earliest maturing varieties, are photoperiod-sensitive and typical short-day plants (Shanmugasundaram, 1981) *viz*., they are affected by the relative length of day and night. Short-day plants flower only when the length of the day is less than a critical value. The long summer days of high latitude regions such as the Pacific Northwest combined with relatively cool summer temperatures make it necessary to choose a variety which matures early and is less sensitive to photoperiod (Miles, 2000).

Interaction of photoperiod and temperature often directly affect soybean (*Glycine max* L.) breeders and producers when selecting varieties, determining dates of planting, predicting dates of flowering and maturity and predicting final yield (Raper and Kramer, 1987; Zhang *et al*., 2001). Effect of the photoperiod response on area of adaptation is more pronounced in the soybean than in any other major crops (Alliprandini *et al*., 2009). As soybean is classified as short-day plant, sensitivity to photoperiod is a hindering factor in increasing its adaptation range (Alliprandini *et al*., 2009). When soybeans are cultivated under short-day condition, in out-of-season plantings or in low latitude, those plants with the classic response to photoperiod flower early and result in short plants and low grain yield (Carpentieri-Pipolo, *et al*., 200).

Relative maturity group (MG) of soybean [Glycine max (L.) Merr.] describes the day length responsiveness and overall length of the growing season. Soybean varieties differ in the amount of time spent in vegetative growth before the plant blooms, which is influenced by MG and planting date (Boerma & Specht, 2004; Ortel *et al*., 2020). Soybean yield is also a product of the number of days of seed fill and the rate of fill. The vegetative growth – the leaves – are the plant's factory. The more leaves, the greater the fill. The significance of this is that as you move up the maturity groups, the plants have a bigger factory before flowering begins. That should maximize yields.

Like all soybeans, *edamame* is ranked in maturity groups of 0-8, where 0 represents the earliest maturation and 8, the latest. In the Pacific Northwest, a variety with a ranking of 0-3 is cultivated. Varieties in these early maturity groups are listed as maturing in 70-90 days; however, this maturation period is not accurate for the Pacific Northwest, where the varieties take 100-120 days to mature. To calculate maturity for the Pacific Northwest, add 25-40 days to the “days to maturity” presented in most seed catalogues. Soybean breeders have developed thirteen maturity group ranging from 000 to X. Maturity group 000 (triple zero) would designate soybean varieties adapted to tropical regions. Many companies or institutions now use Arabic numbers for maturity groups and divide each maturity group into tenths (for example 2.9 or 5.8). If planted in mid-May, a full season variety (for a given location) will mature before the first frost (late September to early November). Maximum yield is usually obtained by using a full season variety.

CONCLUSION

A wide adaptability and deliciousness of *edamame* offer a feasible and ideal option to combat malnutrition, particularly protein and iron deficiencies in India. However, some improvements need to be made, such as developing a bean with a flavor with more acceptability and good eating quality. Vegetable soybeans have the added benefit of helping to farm sustainably as the plants can be used as healthy fodder or green manure. Vegetable soybean may represent a profitable alternative crop providing more choices to replace or rotate with traditional crops. The work on economic efficiency through improved agrotechnology is need to be done. Developing *edamame* cultivars with high seed vigor and better adaption to the local soil and climate, as well as optimizing the conditions of seed processing and storage should be a goal for plant breeders and seed industries to improve seed quality and *edamame* emergence.

Large seeds of *edamame* are relatively more sensitive to poor edaphic and environmental conditions including inadequate soil moisture, improper temperature, and soil obstruction. Large seeds also are more prone to reduce viability and vigor because of mechanical damage during seed harvesting and processing, and are more likely to age during storage. As large seeds leach more nutrition during imbibition, attracting soilborne pathogens and increasing disease occurrence. All of these factors contribute to the lower emergence ability of *edamame* in the field when compared with that of grain-type soybean seeds. Considering above facts, breading for new domestic *edamame* varieties is highly recommended. Further, the elemental and phytochemical properties of *edamame* and their *in vitro* biological availability should also be considered.

REFERENCE

AICRP (Soybean). 2023. Annual Progress Report. ICAR-Indian Institute of Soybean Research, Khandwa Road, Indore 452 001 (M.P.) India

Alliprandini, L.F., Abatti, C., Bertagnolli, P.F., Cavassim, J.E., Gabe, H.L., Kurek, A., Matsumoto, M.N., Rott de Oliveira, M.A., Pitol, C., Prado, L.C. and Steckling, C. 2009. Understanding Soybean Maturity Groups in Brazil: Environment, **c**ultivar **c**lassification, and **s**tability**.** *Crop Science*, **49**. (*https://doi.org/10.2135/cropsci2008.07.0390*).

Anonymous. 2019. https://fdc.nal.usda.gov/fdc-app.html#/food-details/174271/nutrients.

Belagali, L. and Kulkarni, U.N. 2016. Acceptable entity of vegetable soybean. Journal of Farm Science, **29**: 509-512.

Boerma, H. R., & Specht, J. E. (2004). Soybeans: Improvement, production, and uses (3rd ed). Madison, WI: ASA, CSSA, and SSSA. https://doi.org/10.1016/j.agsy.2004.06.006.

Carson, L.C. 2010. Cultivation and nutritional constituents of Virginia grown *edamame*. Master's thesis, Virginia Tech University, Blacksburg, VA.

Carson, L.C., Freeman, J.H., Zhou, K., Welbaum, G.E. 2012. Antioxidant capacity and isoflavone content in seeds of five *edamame* (*Glycine max* L. Merrill) cultivars. *Proceedings of the Florida State Horticultural Society* **125**:169-173.

Chadha, M.L. and Oluoch, M.O. 2004. Vegetable soybean research and development in Africa. In: *International Vegetable Soybean Conference*. Brazil.

Chen, Y., and Nelson, R.L. 2004. Evaluation and classification of leaflet shape and size in wild soybean. *Crop Science* **44**, 671-677. doi: 10.2135/cropsci2004.6710

Dhakal, K., Q., Zhang, B., Li, M. and Li, S. 2021. Analysis of shoot architecture traits in *edamame* reveals potential strategies to improve harvest efficiency. *Frontiers in Plant Science* **12**:614926. doi: 10.3389/fpls.2021.614926.

Djanta, M.K.A., Agoyi, E.E., Agbahoungba, S., Quenum, F.J., Chadare, F.J., Assogbadjo, A.E., Agbangla, C. and Sinsin, B. 2020. Vegetable soybean, *edamame*: Research, production, utilization and analysis of its adoption in Sub-Saharan Africa. *Journal of Horticulture and Forestry*, **12**: 1-12.

Dunna, D.S., Heisnam, N.D., Thokchom, R.D., r Sinha, B. and Singh, O. 2023. Principal component analysis among vegetable soybean genotypes (Glycine max L. Merrill). Environment Conservation Journal: doi - https://doi.org/10.36953/ECJ.14532442.

Elhady, A., Hallmann, J. and Heuer, H. 2020. Symbiosis of soybean with nitrogen fixing bacteria affected by root lesion nematodes in a density-dependent manner. *Scientific Reports* **10**:1619. (*https://doi.org/10.1038/s41598-020-58546-x*).

Esler, I. 2011. Prospects for vegetable soybean in India and its market acceptance: Research and cultural experiences in Hyderabad, India. Hyderabad.

F.A.O. 2022. (*https://www.fao.org/hunger/en/#:~:text=What%20is%20food%20insecurity%3F,an%20 active % 20and%20healthy%20life*).

Fehr, W.R., Caviness, C.E., Burmood, D.T. and Pennington, J.S. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.). Merrill. *Crop Science* **11**:929–931.

Fenta, B.A., Beebe, S.E., Kunert, K.J., Burridge, J.D., Barlow, K.M., Lynch, J.P. and Foyer, C.H. 2014. Field phenotyping of soybean roots for drought stress tolerance. *Agronomy* **4**: 418–435. doi: 10.3390/agronomy4030418

Ghassemi-Golezani, K., Taifeh-Noori, M., Oustan, S. and Moghaddam. M. 2009. Response of soybean cultivars to salinity stress. *Journal of Food, Agriculture & Environment*, **7**: 401-404.

Johnson, D., Wang, S. and Suzuki, A. 1999. *Edamame*: A vegetable soybean for Colorado. p. 385–387. In: J. Janick (ed.), *Perspectives on new crops and new uses*. ASHS Press, Alexandria, VA.

Kambhampati, S., Aznar-Moreno J.A., Bailey, S.R., Arp, J.J., Chu, K.L., Bilyeu, K.D., Durrett, T.P. and Allen, D.K. 2021. Temporal changes in metabolism late in seed development affect biomass composition*.* *Plant Physiology*, **186**: 874-890.

Kamle, M., Kumar, P., Patra, K.K. and Bajpai, V.K. 2017. Current perspectives on genetically modified crops and detection methods. *Biotechnology*, 7(3): 219. doi: 10.1007/s13205-017-0809-3.

Keatinge, J.D.H., Easdown, W.J., Yang, R.Y., Chadha, M.L. and Shanmugasundaram, S. 2011. Overcoming chronic malnutrition in a future warming world: the key importance of mungbean and vegetable soybean. *Euphytica* **180**: 129-141.

Koes R, Verwejj W, Quattrocchio F, 2005. Flavonoids: a colorful model for the regulation and evolution of biochemical pathways. *Trends Plant Science* **10**: 236-42.

Kokobun, M. 1991. Cultural practices and cropping systems for vegetable soybean in Japan. In: *Vegetable Soybean: Research Needs for Production and Quality Improvement*. National Agriculture Research Center, Japan. Pp. 53-60.

Konovsky, J., Lumpki,n T.A., Mcclary, D. 1994. *Edamame*: The vegetable soybean. In: understanding the Japanese food and agri-market, a multifaceted opportunity (AD editor, O‟Rourke)w, Binghamton, pp. 173-181.

Lee, J.Y., Popp, M.P., Wolfe, E.J., Nayga, R.M. Jr., Popp, J.S., Chen, P. and Seo, S. 2018. Information and order of information effects on consumers' acceptance and valuation for genetically modified *edamame* soybean. *PLoS One* **13:** e0206300. doi: 10.1371/journal.pone.0206300

Li, Y.S., Du, M., Zhang, Q.Y., Wang, G.H., Hashemi, M. and Liu, X.B., 2012. Greater differences exist in seed protein, oil, total soluble sugar and sucrose content of vegetable soybean genotypes [*Glycine max* (L.) Merrill] in Northeast China. *Australian Journal of Crop Science* **6**: 1681-1686.

Liu, K.S. 1999. Soybeans: chemistry, technology, and utilization. Aspen Publishers, Inc., Gaithersburg, MD

Liu, Y., Du, H., Li, P., Shen, Y., Peng, H., Liu, S., Zhou, G., Zhang, H., Liu, Z., Shi, M., Huang, X., Li, Y., Zhang, M., Wang, Z., Zhu, B., Han, B., Liang, C. and Tian, Z. 2020. Pan-genome of wild and cultivated soybeans. *Cell* **182:** 162–176.e13. doi: 10.1016/j.cell.2020.05.023.

Longvah, T., Anathan, R., Bhaskarachary, K. and Venkaiah, K. 2017. Indian Food Composition Tables 2017. Published by National Institute of Nutrition, ICMR, India.

Lumpkin, T.A. and Konovsky, J. 1991. A critical analysis of vegetable soybean production, demand, and research in Japan. In: *Vegetable Soybean, Research Needs for Production and Quality Improvement*. Washington State University. Pp. 121-130.

Mahoussi, K.A.D., Eric, E.A., Symphorien, A., Florent, J.B.Q., Flora, J.C., Achille, E.A., Clement, A. and Brice, S. 2020. Vegetable soybean, *edamame*: research, production, utilization and analysis of its adoption in sub-saharan Africa. *Journal of Horticulture and Forestry*, **12**: 1-12. doi: 10.5897/JHF2019.0604

Mausda, R. 1991. Quality requirement and improvement of vegetable soybean. In: *Vegetable Soybean, Research Needs for Production and Quality Improvement*. National Food Research Institute, Ministry of Agriculture, Forest and Fisheries, Japan. 92-102

Mentreddy, S.R., Mohamed, A.I., Joshee, N. and Yadav, A.K. 2002. *Edamame*: a nutritious vegetable crop. In: *Trends in New Crops and New Uses* (J Janick and A Whipkey, editors). Alexandria, VA: ASHS Press pp. 432- 438.

Messina, M., 2001. An overview of the health effects of soyfoods and soybean isoflavones. In: *2nd International Vegetable Soybean Conference* (Lumpkin T.A., Shanmugasundaram S. eds.), Washington State Univ., Pullman, PA, USA. pp. 117-2

Miles, C.A., Lumpkin, T.A. and Zenz, L. 2000. *Edamame*. Farming West of the Cascades series - Food and Farm: http://www2.hawaii.edu/~theodore/Images/*edamame*.pdf.

Morse, J.L. and T.E. Carter, Jr. 1952. Soybeans for feed, food and industrial products. p. 41. Farmer's Bul. 2038, U.S. Department of Agriculture

Nair, R.M., Boddepalli, V.N., Yan, M., Kumar, V., Gill, B., Pan, R.S., Wang, C., Hartman, G.L., Silva e Souza, R. and Somta, P. 2023. *Plants*, **12***:* 609; https://doi.org/10.3390/plants12030609.

Nataraj, V., Pandey, N., Ramteke, R., Verghese, P. Reddy, R., Onkarappa, T., Mehtre, S.P., Gupta, S., Satpute, G.K., Mohan, Y., Shivakumar, M., Chandra, S. and Rajesh, V. 2020. GGE biplot analysis of vegetable type soybean genotypes under multi-environmental conditions in India. *Journal of Environmental Biology*, **42**: 274-53.

Ortel, C.C., Roberts, T.L., Hoegenauer, K.A., Purcell, L.C., Slaton, N.A., and Gbur, E.E. 2020. Soybean maturity group and planting date influence grain yield and nitrogen dynamics. *Agrosystems, Geoscience and Environment*, **3**: e20077.

Pan R.S., Singh, A.K. and Rai, M. 2004. Vegetable soybean: a promising new introduction in Jharkhand for nutritional security. *Journal of Research (BAU)*, **16**: 71-74.

Patil, V., Meti, S., Mansur, C.P., Rajashekhara, E., Prabhaker, I., Hadimani, H.P. and Kaviraja, H. 2017. Nutritional Studies on Vegetable Soybean [*Glycine max* (L.) Merrill], in Northern Dryzone of Karnataka, India. *International Journal of Current Microbiology and Applied Sciences*, **6**: 5364-5374.

Poornima, R., Koti, R.V. and Nair, M.R. 2014. Physiological basis of yield variation in vegetable soybean and organoleptic test for acceptance. *Plant Archives*, **14**: 51-54

Ravishankar, M., Pan, R.S., Kaur, D.P., Giri, R.R., Kumar, V.A., Rathore, A., Easdown, W. and Nair, R.M. 2016. Vegetable Soybean: A Crop with immense potential to improve human nutrition and diversify cropping systems in Eastern India- A Review. *Soybean Research*, **14**: 01-13.

Reddy, M.R., Poshadri, A., Chauhan, S., Prashanth, Y. and Reddy, R.U. 2019. Evaluation of soybean lines for *edamame* (*Glycine max* (L.) Merrill) as a potential vegetable for Telangana state of India. *International Journal of Current Microbiology and Applied Sciences*, **8**: 552-560.

Shanmugasundaram, S. and Yan, M.R. 2010. Vegetable soybean. In: *The Soybean - Botany, Production and Uses* (G Singh ed.), CAB International Publishing, Wallingford, UK, pp. 427-60.

Shanmugasundaram, S., 1996. The evolving global vegetable soybean industry. In: *Proceedings of 2nd International Soybean Processing and Utilization Conference* (Duchanan A. ed.). Bangkok, Thailand. pp. 472-8.

Shanmugasundaram, S., Yan, M.R. and Yan, R.Y. 2001. Association between protein, oil and sugar in vegetable soybean. In: *Second International Vegetable Soybean Conference* (T. Lumpkin editor), Pullman, Washington. Washington State University. 202

Shurtleff, W. 2001. On the English-language etymology of "green vegetable soybeans," "*edamame*," "vegetable-type soybeans," and "food-grade soybeans." p. 179–181. In: T.A. Lumpkin and S. Shanmugasundaram (Compilers), 2nd Int. Vegetable Soybean Conf., Washington State Univ., Pullman

Shurtleff, W. and Aoyagi, A. 2001. Chronology of green vegetable soybean and *edamame* (including maodou) Worldwide. https://www.soyinfocenter.com/chronologies_of_ soyfoods-*edamame*.php.

Shurtleff, W. and Aoyagi, A. 2009. History of *edamame*, green vegetable soybeans, and vegetable-type soybeans (1275-2009): Extensively annotated bibliography and sourcebook. Soy info Center, Lafayette, CA, USA.

Shurtleff, W. and Lumpkin. T.A. 2001. Chronology of green vegetable soybeans and vegetable-type soybeans. In: *2nd International Vegetable Soybean Conference* (T.A. Lumpkin and S. Shanmugasundaram (Compilers), Washington State Univ., Pullman. pp. 97–103.

Singh, C., 1983. Modern techniques of raising field crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp: 301-302.

Singh, S., Kapila, R.K. Kanwar, R. and and Dhiman, K.C. 2021. Characterisation of soybean varieties of Himachal Pradesh using morphometric descriptors. Himachal Journal of Agricultural Research, 47(1): 50-60.

Smith, R.S., 1992. Legume inoculant formulation and application. *Canadian Journal of Microbiology* **38**: 485-492.

Song, Q., Hyten, D.L., Jia, G., Quigley, C.V., Fickus, E.W., Nelson, R.L. and Cregan, P.B. 2013. Development and evaluation of SoySNP50K, a high-density genotyping array for soybean. PLoS One **8**:e54985. doi: 10.1371/journal.pone.0054 985.

Takahashi Y and Ohyama T. 2011. Production and consumption of green vegetable soybeans - *Edamame*‖, In: Soybeans: Cultivation, Uses and Nutrition, Maxwell J E (Ed), pp. 427-44.

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 (S. Shanmugasundaram, editor), Taiwan: Asian Vegetable Research and Development Center. Pp. 103–07..

Weber, C.R. 1956. New and better vegetable soybeans. *Farmer Science* **10**:1314

William, S. and Aoyagi, A. 2009. History of *edamame*, green vegetable soybeans and vegetable-type soybeans. Lafayette, CA: Soyinfo Center.

Williams, M.M., II, Zhang, B., Fu, X. and Ross, J. 2022 Editorial: everything *edamame*: biology, production, nutrition, sensory and economics. *Frontiers in Plant Science* **13**:976008. doi: 10.3389/fpls.2022.976008.

Wu, Q.L., Wang, M.F., Sciarappa, W.J. and Simon, J.E., 2004. LC/UV/ESIMS analysis of isoflavones in *edamame* and tofu soybeans. *Journal of Agriculture and Food Chemistry* **52**: 2763-9.

Xavier, A., Hall, B., Hearst, A.A., Cherkauer, K.A., and Rainey, K.M. 2017. Genetic architecture of phenomic-enabled canopy coverage in *Glycine max*. *Genetics* **206:** 1081–1089. doi: 10.1534/genetics.116.198713.

Yoshiki, M., Sachie, H., Toshihide, M., *et al*. 2013. Soybean as a nitrogen supplier. a comprehensive survey of International Soybean Research - Genetics, Physiology, Agronomy and Nitrogen Relationships. *InTech*. doi: 10.5772/51017.

Yu, X., Fu, X., Yang, Q., Jin, H., Zhu, L. and Yuan, F. 2022. Genome-Wide Variation Analysis of Four Vegetable Soybean Cultivars Based on Re-Sequencing. *Plants*, 11: 28. https://doi.org/10.3390/ plants11010028

Zhang, L., Kyei-Boahen, S. 2007. Growth and yield of vegetable soybean (*edamame*) in Mississippi. *HortTechnology* **17**:26-31.

Zhang, L., Wang, R. and Hesketh, J.D. 2001. Effects of photoperiod on growth and development of soybean floral bud in different maturity. *Agronomy Journal*, **93**: 944-948.