Varietal Yield Stability and Appropriate Management for Quality Organic Edamame Production

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Nature's Path Foods

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EXECUTIVE SUMMARY

Edamame is the popular name of vegetable soybean (*Glycine max,* L (Merrill.). This crop has been grown mostly in Asia, particularly Japan, Taiwan, China, Thailand, Indonesia and Vietnam. Edamame is one of the top sources of quality human nutrition. It is also a crop of high potential for enriching soil fertility and productivity, while adapting to climate change. Its high quality protein, dietary fiber, Omega 3- fatty acids and micronutrients enriches its clinical and medicinal value. It is a rising star found in the frozen foods section of grocery stores. Japan and North America are major importers and its present global market demand is met by China, Taiwan, Thailand and Indonesia. Its rising market demand in importing countries, and increasing cost of production in exporting countries, has opened an opportunity in North America for edamame research, education and promotion. Some universities and government organizations in the US and Canada are already focusing on research and development of this valuable crop. Research and development efforts are aimed at bringing this crop into viable commercial cultivation to meet domestic demand and look for export potential. Agriculture and Agri-Food Canada in Ontario are calling for taste evaluation of newly developed locally adapted varieties of edamame for commercial cultivation. The "grow and buy local initiative" of BC is an excellent opportunity to research and promote locally produced organic edamame, thus supporting human nutrition, regional food security and climate adaptation.

Past studies have indicated the possibility of successful cultivation of edamame in the Pacific Northwest region, provided fine-tuned management packages are developed and practiced. This study was conducted to identify fine-tuned management practices and confirm the yield stability of high quality organic edamame in locations that differ in soil type and micro-climate in BC's lower Mainland. Seven varieties were grown at The Sharing Farm (TSF) in Richmond and UBC Farm (UBCF) in Vancouver: SPS-BL 3, SPS Isophenic, Haruno-Mai, Sayamusume WCS, Sayamusume TSC, Shirofumi and Beer Friend. The experimental plot was planted on May 31 in 10 ft long 42" spaced single rows, each with narrow (3") and wide (4") plant spacing, which was replicated twice at UBCF. Edamame was planted at TSF on June 4, 2013 in two 6 ft long 21" spaced rows, each with narrow and wide plant spacing. Soil at both sites was not amended. Crops received scheduled drip irrigation at UBCF, while the crop was lightly irrigated at critical stages of development at TSF. Crop phenology was monitored and recorded. Green pods were harvested from twenty plants and ten plants from each experimental unit at TSF and UBCF, respectively.

Varieties differed in performance in similar manner at both locations, exhibiting yield stability with less effect of location. Moderate fertility, friable, warm, moist organic soil and healthy seeds are the most important factors for a successful crop, followed by proper weed control and moisture management. Cold wet soil and root rotting fungus were the threats for proper seedling establishment. Wider spacing to produce 3-4 productive branches resulted in a high yield of quality pods; conversely, narrow spacing discouraged branching, and hence lowered yield. Though edamame is a drought tolerant crop, adequate soil moisture at R 6 stage promotes the pod's market quality and prolongs the harvest period. Sayamumusume TSC showed the highest yield, with high quality pods for longer harvest period. This variety was followed by SPS- BL 3 and, SPS Isophenic. Shirofumi is high yielding but late for Metro-Vancouver's climate, and Beer Friend, Sayamusume WCS and Haruno-Mai had low yields. In conclusion, the successful production of edamame in lower mainland, as demonstrated by varietal adaptation and yield stability studies, indicates that organic farms of any agro-climatic pockets of BC with equal or warmer, drier or sunnier climates than Richmond are suitable for quality edamame production under fine-tuned management. Duncan, Grand Fork and Kelowna are potential pockets for producing regionally adapted high quality seeds for the local food system, contributing to quality nutrition and food security.

INTRODUCTION

Soybean (Glycine max L. Merrill) “star legume” (UDSA 1998) is a popular source of quality nutrition. There are two types of soybean: a) commodity soybean harvested for grain and b) vegetable soybean harvested for green pods, popularly called “edamame” in Japan ‘mao dou’ in China, and ‘poot kong’ in Korea. Commodity soybean is the most widely grown legume in the world whose production is dominated by USA and Brazil. However, Japan, China, Korea and Taiwan were the major producers and consumers of vegetable soybean in the past. Japan continued producing 110,000 tons per year from 1988 to 1992 which dropped to 70,000 tons in 2004 (Sanmugasundaram and Yan 2004). This caused an import of 70,000 tons from other countries. Taiwan monopolized the export market to Japan until 1992. Until recently, 50%, 34%, 13% and 3% of the total export to Japan is made by China, Taiwan, Thailand and other countries including Indonesia, and Vietnam. Both organic and inorganic edamame are grown in exporting countries. Pubs and bars, mostly in East and West coastal cities of North America introduced edamame by serving it in place of peanuts, creating a new craze. Popularization of Susi restaurants serving edamame promoted its market demand. A new craze was born, and Americans have taken notice in a big way. Japan and USA were two countries making major demand of 87.7% and 11.7% frozen edamame globally (Shamugasundaram 2001) which still is true at present.

Nutritional Fact

Soybeans in general are rich in protein, carbohydrates, dietary fiber, omega -3 fatty acids and other micronutrients (Anonymous 2011). It is real “green” food for all, especially for vegans. A half-cup serving of edamame is equivalent to four ounces roasted chicken breast and four slices of whole wheat bread with respect to protein and dietary fiber (Anonymous 2010), respectively. One hundred grams of frozen edamame provides around 122 calories and contains 11 grams protein, 10 grams carbohydrate, 5 grams each of dietary fiber and fat (0.3 gm plant omega -3 fatty acid) and 2 grams sugar (Anonymous 2005). It is good source of sodium, iron, calcium, potassium, phosphorous and magnesium and also folate, vitamins A, B1, B2, B3, C, E and K (Nair 2010). Isoflavones (phytoestrogens), a protein that reduces bad cholesterol and raises good cholesterol and functions against hypertension, osteoporosis, cancer and heart diseases (Magee 2012) adds value to edamame.

Recipes and Uses

Vegetable soybean is a large seeded (>30 g/100 seeds dry weight), slightly sweeter type of soybean, which is harvested and sold as pods-on-stems, loose pods, or shelled beans. These tasty beans are highlighted in 60 recipes ranging from appetizers and soups to salads, side dishes, and a host of main dishes (Anne Egan 2007). The Pods-on-stem form is still popular in Japan, partially because appearance and flavor factors decline more slowly after harvest while pods remain attached to the stem. Shelled beans are also used in salads, soups, stews and dips or mixed with other vegetables (Anonymous 2011). In Japan, sticky rice topped with sweetened edamame paste (zunda mocha) is occasionally prepared (Lupkin et al. 1993). In Korea the beans are added to rice and cooked together (pub mi kong). Because of the rising demand, edamame is easily available in frozen food section of almost any grocery store of North America.

Research in North America

Research activities on edamame started in the United States as early as 1929 (Hymowitz 1984) and flourished during the 1930s and 1940s because of protein shortages (Smith and Duyne 1951). A second surge of research began with the interest in organic farming in the 1970s (Hass et al. 1982). Asian-Americans seeking edamame are usually limited to frozen imports in specialty supermarkets. The basic agronomic research began at Cornell University (Kline 1980). Washington State University started a variety development program in 1995 to select varieties suited to the relatively cool growing season of the Pacific Northwest (Miles and Sonde 2002). Today, home gardeners from Arkansas to Minnesota grow edamame, but there is little commercial production. American Sweet Bean Company in Ohio has been growing edamame since 2005 and now produces certified organic edamame (Anonymous 2008). The efforts of the University of Arkansas to bring edamame into commercial production have helped establish American Vegetable Soybean and Edamame Inc. (AVS) in Mulbery. As a result, the city of Mulbery in Arkansas has been named as 'Edamame Capital' of the US. AVS targets to meet the 12-15% annual rising demand in USA created by increased awareness on the benefit of healthy diets. AVS aims to export frozen edamame to other parts of the world (Anonymous 2012).

The demand for edamame has also grown in Canada. Jacob MacKellar, owner of a 3000 acre farm in southwestern Ontario initiated an effort to replace imported frozen edamame with Canadian product and received the Premier's Award for Agri-Food Innovation Excellence (Anonymous 2011). The Greenhouse and Processing Crops Research Centre of Agriculture and Agri-Food Canada (AAFC) at Harrow Ontario has developed a high yielding (3.6 ton/ha and large seeded 30 g/100 seeds) food grade soybean variety 'OX-135' for the edamame market. AAFC is fielding marketing proposals for the quality evaluation of that edamame variety (Anonymous 2011). Sharma (2013) , in his edamame varietal adaptation study, reported pod yields of large seeded varieties as high as 14 tons/ha. However, fine-tuned management practices are necessary for successful stand establishment and high yields in the Pacific Northwest climate.

Human and Soil Health Benefit

The majority of fruits and vegetables available in urban markets are products of conventional agriculture (agro-chemical intensive and genetically engineered seeds) and are transported from long distances. This fact has raised questions of food mileage, carbon foot print, health risks and urban food security. The health risk from the consumption of non-organic food and increased health care cost is being acknowledged. Conventional farming has also contributed significantly to the climatic crisis of erratic and extreme weather, making agriculture more unstable and unsecure. Edamame, an 'emerging new crop' with the inherent ability to fix atmospheric nitrogen, is better adapted to climate change, can enrich soil ecology and fertility and can generate income, increase jobs, improve nutrition, and improve the sustainability of the agro-eco system. The total biological yield of vegetable soybean can be as high as 40 t/ha in 75 days, consisting of 10 tons of marketable pods and 30 tons of residues that can enrich soil or feed animals (Shanmugasundaram and Yan 2004). Organic residue is a valuable component in a regenerative organic agriculture system, increasing agricultural quality, productivity, restoration of environmental degradation, and human health through more nutrient dense food (Lotter et al. 2003). Sharma and Kshattry (2013) reported increased soil productivity and fertility by growing edamame under medium organic fertility and reduced irrigation as an effort to adapt to climate change.

Crop Management

Edamame is a specialty soybean and fine-tuned management is necessary to market a high quality product directly to consumers. Flavor, sweetness, texture, nutritional value, and visual appearance are key quality components of edamame (Sharma and Kshattry 2013). Sucrose, glutamic acid, and alanine are important for flavor; sweetness is influenced by the sugar levels in the beans; and harvest timing commonly affects bean texture. Dark green pods, free from defects, and containing 2 and 3 beans per pod are desirable market quality. Agronomic practices can have a significant effect on quality assurance for edamame (Nelson et. al. 2011). Miles et.al., (2000) recommended the application of 50 to 120 lbs of nitrogen per acre and Nguyen 2001 recommended side-dress application of potassium nitrate in Washington. However, Sharma (2012) observed a negative effect of luxurious production environment and reported the possibility of growing organic vegetable soybean under medium fertility and reduced irrigation in Richmond, BC. Though edamame soybean is tough in drought conditions and clay soil, well-drained, friable and warm soil conditions are necessary for germination and emergence (Chase 2007). The plant population that gives a high yield of high quality pods is variable with soil fertility, productivity and climate during entire growing season. Nelson et al., (2001) reported 25, 19, and 16 pod yield/plant and 4.2, 5.2 and 6.3 ton/ha for 98,000, 170,000, and 245,000 plants/ha, respectively. However, high plant population results in higher yields of poor market quality pods. Therefore, 150,000 to 180,000 plants per hectare is recommended (Nelson et. al. 2001). Large seed with a high percent of 2 and 3-beans per pod showed negative correlation with plant population, plant height and days to maturity in Richmond, BC. Denser population increased the plant height by reduced branching and produced poor quality edamame compared to thinner population with shorter height and increased branching. This requires further study to test for varietal yield stability and to determine optimum plant population for high yield of marketable quality edamame under organic management in BC (Sharma and Kshattry 2013).

Production of fresh organic edamame supports food security, better health, and has environmental benefits. The "OSDP Project # I-142" has the following specific objectives: i) to conduct yield stability study of promising varieties from Phase I plus other popular varieties at two locations and confirm findings of 2012 before making any scientific recommendation based on only one year result, ii) to determine appropriate spacing to produce marketable high quality edamame required for creating viable market, and iii) to connect and share results with local organic growers, researchers from the ministry, universities and seed growers to accomplish the long term goal of developing edamame as a viable commercial crop in BC.

MATERIAL AND METHODS

Research Site and Field Preparation

Two experiment sites adopting organic production practices but differing in soil texture, fertility and micro-climate were used for the purpose of this study:

I. The Sharing Farm, Terra Nova Rural Park, Richmond, BC; and

II. University of British Columbia Farm (UBC Farm).

I. The Sharing Farm

An area of 90 ft x 40 ft of the East Field was allocated for the edamame soybean study. The land is dominated by clay silt soil and was amended with composted manure in the previous year. It was covered with weeds of different species when visited on May 20, 2013 (Figure 1). The field was disked on May 21 and tilled on June 3, 2013 when it was dry. Of the total area, an area of 60 ft x 30 ft was selected and three blocks were created to minimize the soil heterogeneity. No manure of any kind was added for fertility. The experiment was laid out in complete randomize block design. Fifty one feet long blocks were separated by three feet distance between blocks. Six feet long four rows made whole plot which was divided into two sub-plots to represent two different plant spacing categorized as **a) narrow spacing (3.5 plants/ft) and b) wide spacing (2.5 plants/ft)**. Seven varieties of edamame soybeans (Table 1) were planted on June 4, 2013 maintaining a distance of 21 inches between rows. Seed rate was adjusted to 80 percent germination. Since the soil was not friable because of soil texture and minimum tilling, every effort was made to keep seeds away from small dry clay clods while planting. Required plant population was maintained by gap filling and thinning to represent two different spacing. Weeds were controlled by frequent hand weeding and plants were supported with additional soil pulled over to the base of plants from inter row spaces while hoe weeding at V3-V4 stage. Crop growth was regularly monitored and irrigated by hand hose only at critical stages (Appendix III) guided by week long weather forecast to avoid moisture stress which was judged by close observation of plant response.

Table 1. List of varieties included in study, source of seed and flower and seed morphology

Variety	Source of Seed	Flower and Seed Character
SPS-BL-3	Sharing Farm (Salt Spring Seed)	White flower, large size seed
SPS-Isophenic	Sharing Farm (Salt Spring Seed)	White flower, medium large size seed
Haruno-Mai	Sharing Farm (Salt Spring Seed)	White –cream flower, medium size seed
Sayamusume WCS	Sharing Farm (West Coast Seed)	White flower medium size seed- short plant
Sayamusume TSC	Sharing Farm (Territorial Seed)	White flower, medium size seed- tall plant
Shirofumi	Sharing Farm (Anapolis Seed)	White flower, medium size seed
Beer Friend	UBC Farm	White flower, medium size seed

Note: Information within parenthesis indicates the original source of seed. SPS- BL= Single Plant Selection –Breeding Line, selected from population grown at Sharing Farm in 2010.

Figure 1. Research field at The Sharing Farm on May 20 and June 3, 2013 from left to right.

II. UBC Farm

The field D4-1 South section of the farm with sandy silt loam soil was used for the study. Mushroom manure and lime was added in the spring of 2012 and a cover crop of fall rye, crimson clover and vetch was plowed under in May 6, 2013. The field was disked three weeks after and tilled before planting. No manure was added for the crop in 2013. Two rows, each 160 ft long spaced 3.5 ft apart, were used to plant the experiment on May 31, 2013. Ten feet long four rows for each variety represented main plot which was divided into two rows sub-plots to represent two different spacing categorized as **a) narrow spacing (3.5 plants/ft) and b) wide spacing (2.5 plants/ft**) . The seed rate was adjusted after germination to maintain the desired plant density.

Figure 2. Tilling and opening 42" spaced rows for planting and drip irrigation at UBC in 2013

Crop Management and Data Recording

The crop at both sites was hand weeded to control weeds. Crop at UBC Farm was irrigated three times a week, 2 hours each through drip irrigation while at The Sharing Farm, it was overhead hand hose irrigated at critical period of growth when dry spell continued for more than two weeks (Appendix III). Plant growth, reproductive development, disease development and insect occurrence were regularly monitored right from seedling stage. Five plants from each row were identified and tagged at V5 stage for data recording for respective spacing. Data on plant stand, days to 50% flowering, canopy height ((measured from base of the plant to top of the foliage) and plant height (measured from base of the plant to the end of terminal raceme) and days to edamame pod harvest were recorded in the field. All tagged plants from each row were cut from the ground at R 6 stage.

Figure 3. Seeds for germination test (right) and field planted (left).

Number of productive branches per plant and total number of nodes on main stem were also recorded. All pods from each plant were picked and categorized into 1-bean pod, 2-bean pod and 3-bean pod which was converted into percent of each pod type.

Edamame soybean pod yield of tagged ten and five plants each for two spacing from The Sharing Farm and UBC Farm, respectively was recorded. Pod yield per plant was converted into yield per plot in grams by multiplying by 35 and 25 to represent narrow and wide spacing. Six ft long two rows spaced 21” (1.89 square meters) and 42” (3.78 square meters) apart represented size of plot at the Sharing Farm and UBC Farm, respectively. The pod yield per plot was then converted into yield per hectare. Weight of 100 well developed fresh pods containing 3-beans each was recorded in order to compare the size of beans. Harvesting for seed saving took extra efforts because of wet weather during entire month of September and early October. Matured pods of early varieties from both locations were picked and air dried in room temperature. Pods were shelled and seeds were dried until they were hard when felt between two fingers. Plants of late maturing varieties were cut and hung in bundle under shaded porch for air drying to prevent from mold development. Weight of 100 dry seeds was recorded.

Data Analyses

We used STATA ® software version 12.0 (STATA Corp, Texas, USA) to analyze the data. Test of significance was done using two- way analysis of variance (ANOVA). Post-hoc means separation was done by using Tukey’s- Kramer HSD test. Bivariate and multivariate relations were assessed using Pearson’s product-moment correlation test.

Soil Analysis

Soil Source	pH	E.C mmhos/cm	Organic matter %	Total N %	Available P (ppm)	Available K (ppm)	Available Ca (ppm)	Available Mg(ppm)
SF #1	6.8	0.62	6.1	0.27	210	435	2400	245
SF #2	6.6	0.66	5.8	0.26	221	415	2500	255
UBCF #1	6.5	0.62	10.1	0.36	92	165	2100	140
UBCF#2	6.6	0.52	10.1	0.36	118	80	2200	130

All samples were analyzed on September 20, 2013 at Pacific Soil Analysis Inc., Richmond, BC.

SF= Sharing Farm; UBCF= UBC Farm; #1= Before planting; #2 = After crop harvest.

RESULTS

Soil fertility and texture of the experiment field were better at UBC Farm than at The Sharing Farm (Table 2). Seed germination and seedling emergence began after a week at both locations. Seedling emergence was easier at UBC Farm than at The Sharing Farm, which was attributed to soil texture differences. Seed fungal infection and soil borne fungus in wet soil caused seed and seedling rotting at both locations, which resulted in poor germination and seedling emergence in all varieties except Beer Friend and Sayamusume WCS (Figure 4). Seed saving of these two varieties in previous years was done under drier conditions (Table 1). The fields were monitored regularly during the first three weeks, in order to rescue emerging seedlings and fill gaps, so that there were enough plants to create canopy closure. Rows were lightly irrigated to help emerging seedlings at Sharing Farm; this was not necessary at UBC Farm, due to scheduled drip irrigation (Appendix III). Both crop locations looked poor for the first five weeks, as seedlings had challenging fungal and weedy soil conditions, particularly at The Sharing Farm, where fresh weed mass was disked two weeks before one tilling, creating small dry clumps of clay at planting depth (Figures, 4 and 5).

Figure 4. Fungal infection caused poor seed germination and seedling establishment at The Sharing Farm.

Plant population and growth at both locations was not uniform between and within blocks. Heterogeneity in soil fertility and productivity was indicated by differences in growth and development of plants at various corners of the field (Figure 6). Efforts were made by thinning plants six weeks after planting to create uniform plant population for comparative analysis at narrow and wide spacing (Appendix I and II). Crop growth was not vigorous, which was indicated by pale leaf color similar to starter nutrient deficiency. To address this deficiency, soil from inter-row spaces was pulled towards the plant base to create a ridge around the plant root for nutritional support. The crop was kept weed free by regular manual weeding. Crop irrigation at The Sharing Farm was based on growth stage and moisture regime, in coordination with the weather forecast, to save the crop from any drought injury that would affect vegetative and reproductive growth beyond a critical threshold. The crop at UBC Farm received moisture uniformly, via drip irrigation, throughout the growing season.

Figure 5. Gap filled seedlings emerging in between plants of first planting (left) and part of experiment (right) competing with weeds at The Sharing Farm.

Vegetative and Reproductive Development

Crop growth and development sped up in July with record-breaking sunshine hours. Plants started flowering between 50-58 days from planting, depending on varieties. Haruno-Mai and Shirofumi were early and late flowering (Appendix I and II). The crop attained lush vegetative growth towards the end of July and beginning of August (Figure 7). Lush growth occurred more at UBC Farm than at The Sharing Farm, as evidenced by more sunburn injury in the former (Figure 9).

Figure 6.Varietal and block differences at various growth stages of edamame at The Sharing Farm.

Vegetative and reproductive growth continued simultaneously by producing vegetative as well as reproductive buds (Figure 8). However, Beer Friend and Shirofumi differed in growth habit being determinate and semi-determinate, respectively. Sayamusume TSC and SPS-BL 3 were in between Shirofumi and Beer friend with regards to growth habit. Determinate has the advantage of synchronized maturity for machine harvest, while indeterminate growth habit has the advantage of multiple pickings.

Figure 7. Weed control (lower) and block variation with lush growth (upper) of edamame at TSF

Crop canopy height and width continued to grow until the first to second week of August, when the crops achieved full canopy. Canopy height was in general greater at narrow spacing compared to wide spacing; at The Sharing Farm, height ranged from a minimum of 31 cm in SPS Isophenic to 59 cm in Shirofumi (Appendix I). Similarly, canopy height was greater at narrow spacing compared to wide spacing at UBC Farm, which ranged from 41 cm in Haruno-Mai to 63 cm in Sayamusume TSC (Appendix II).

Figure 8. Branching and blooming (left), semi-determinate (middle) and determinate (right) growth habit.

Canopy height and width did not differ much from one location to the other within variety, despite differences in agro-microclimate. This result indicated no significant interaction of variety and location for plant canopy parameters. Pod filling and bean development occurred at the same date in both locations though they differed by five days differences in planting. This was attributed to prolonged vegetative growth at UBC Farm. This was supported by more lush vegetative growth with darker leaves at UBC Farm than of The Sharing Farm which continued until full bean development (Figures 10).

Field Diseases and Insects

Seed rot, root rot and damping off were the major problems causing poor plant stand. The seedlings survived as the soil condition and weather warmed and become drier supporting plant growth. New healthy leaves emerged and picked up good growth suggesting a possible good crop despite the poor start. Puckered leaves and stunted growth were observed at both locations in the early stage of crop growth. Leaf diseases appeared as crop development progressed (Figure 9). Brown leaf spot, white mold and Cercospora leaf and pod blight were major problematic diseases observed more at The Sharing Farm than at UBC Farm. Cercospora blight was more frequent towards the adult crop stage infecting seed. There was no insect damage at either location.

Figure 9. Foliar diseases (sunburn injury, Septoria brown spot, Sclerotinia foliar symptom & stem rot and Cercospora leaf and pod blight, extreme left to right) in edamame grown during 2013.

Yield Components and Yield

Genetic potential for yield can be realized under favorable agro-climate conditions combined with fine-tuned crop management. Yield per plant and plant population per unit area determine total production. Both too high and too low plant population are negative for yield, though these specifications vary with variety and crop species.

Table 3. Mean squares of traits measured on edamame grown at Sharing Farm during 2013.

Source	df	Pl.ht (cm)	Branch #	Node (#)	Pods/ plant (#)	100 pods Wt. (g)	Yield/10 plants (g)	Yield/plot (g)
Blocks	2	466***	12	3**	15 **	9499	158147***	1965022***
Space	1	42	4	2	421***	57	384388***	1905498***
Variety	6	219***	12	12***	135***	5282	159625***	1885106***
Residuals	32	14	0.6	9	25	5836	16630	201568
R-square	41	0 .83	0.25	0.79	0.66	0.21	0.75	0.72

, * Significant at P=0.01 and 0.001, respectively.

Edamame soybean has a quite high ability to compensate for low plant population through branching. Detail data on crop performance at both locations is presented in Appendix II and III. In general, yield and yield components of varieties were similar at both locations except for the percentage of one bean pods, which was higher at UBC Farm. Pod maturity was one week earlier at The Sharing Farm which was indicated by early leaf senescence (Figure 10).

Analysis of variance (Table 3) showed a significant effect of blocking for all traits except branches per plant at The Sharing Farm. Higher yield was obtained at wider spacing at both locations (Table 3 and 4). Varieties differed significantly at both locations for plant height, branches per plant, nodes per plant, pods per plant pod weight, and yield per plant and per unit area. Plant height was a little shorter at The Sharing Farm than UBC Farm but pods per plant and percent 2-bean and 3-bean pods were higher at The Sharing Farm. Edamame pod yield per unit area at The Sharing Farm was more than 40 percent higher than that at UBC Farm which resulted from wider row spacing. Pod yield per plant at both locations did not differ much. However, larger bean size at UBC was primarily a result of greener leaves and delayed senescence, which can be attributed to uniform soil moisture throughout the growth season.

Table 4. Mean squares of traits measured on edamame grown at UBC Farm during 2013.

Source	df	Pl.ht (cm)	Branch (#)	Node (#)	Pods/ plt. (#)	100 pods Wt. (g)	Yield/5 plants (g)	Yield/plot (g)
Replication	1	4	0.6	0.9	37	1922	6977	28912
Space	1	108	0.0	0.0	165*	782	44003	2516401*
Variety	6	310***	3.7***	10***	351***	8314***	66068***	3049343***
Residuals	19	39	0.2	0.9	40	867	11343	589302
R-square	27	0.72	0.84	0.78	0.75	0.76	0.67	0.65

, * Significant at P=0.01 and 0.001, respectively.

Figure 10. Physiological maturity differences of edamame at Sharing Farm (left) and UBC Farm (right).

Branching and pod bearing patterns on edamame were highly determined by plant spacing (Figure 12). Wider spacing was more favorable for branching and higher number of pods resulting in heavier pod production than at narrow plant spacing. Our study showed that crop management favorable to produce 3-4 productive branches per plant would be appropriate for high yield of quality organic edamame (Figure 11 and 12). Most favorable immediate microclimates for individual plants caused significant difference in plant productivity. SPS-BL 3, SPS –Isophenic and Haruno-Mai exhibited a tendency towards higher percent 2- bean, 3- bean and 4- bean pod types than other varieties included in the study (Table 5 and Table 6). Shirofumi produced clusters of pods at lower sections of the plant canopy, whereas Beer Friend produced more pods at the upper middle portion of the canopy. Sayamusume TSC, SPS-BL 3, and SPS- Isophenic produced pods more evenly distributed throughout the canopy than Haruno-Mai and Sayamusume WCS. However, pod cluster and pod size varied among plants within the same variety, which is attributed to the favorable root zone microclimate (Figure 12).

Figure 11. Pod bearing in SPS-BL 3, SPS Isophenic, Sayamusume TSC, Beer Friend and Shirofumi (left to right).

Figure 12. Differences in branching pattern, plant height and, pod quality and quantity, within same variety of edamame grown under wider spacing at Sharing Farm during 2013.

Sayamusume TSC and Shirofumi were taller and produced more branches and nodes resulting in more pods and higher yield per plant at both locations (Table 5 and Table 6). Sayamusume TSC was earlier and produced a high percentage of 3 –bean type pods than Shirofumi. SPS-BL 3 produced the highest percentage of 3- bean type pods followed by SPS-Isphenic and Haruno-Mai. Shirofumi produced the lowest percentage of 3- bean type and highest 2-bean type pods followed by second lowest Beer Friend. Total pods and pod yield per plant was higher under wider spacing but yield per unit area was higher at narrow spacing at both locations without much effect on pod types (Appendix II and III).

Table. 5. Comparison of means for varietal differences in traits of edamame grown at The Sharing Farm during 2013.

Varieties	Pl.ht (cm)	Node #	Pods/ plant(#)	100 pods (gm)	100 seeds (gm)	2-bean pods (%)	3-bean pods (%)	Yield/10 plants (gm)	Yield/ plot (gm)	Yield (ton)/ha
SPS-BL 3	32.8	10.1	35.3	402	32	39.6	48.6	910	3238	17.1
SPS-Isophenic	28.6	9.8	37.6	405	30	40.0	49.1	1004	3537	18.9
Haruno-Mai	31.6	10.1	37.8	377	32	41.1	44.3	939	3350	17.7
Sayamusume WCS	36.3	10.6	31.3	331	33	41.6	41.5	748	2650	14.0
Sayamusume TSC	36.5	12.0	34.1	410	37	50.8	38.0	1126	3936	20.8
Shirofumi	47.6	13.0	44.3	375	33	55.6c	27.5	1087	3817	20.2
Beer Friend	36.6	10.0	30.1	351	35	47.0	36.0	690	2457	13.0
Critical value for differences (CVD)	***14.8***	***1.66***	***13.0***	***=NA***	***3.0***	***5.8***	***10.5***	***339***	***1117***	***5.9***

Means that differ at least by CVD are different from each other.

Table 6. Comparison of means for varietal differences in traits of edamame grown at UBC Farm, 2013.

Varieties	Pl.ht (cm)	Node (#)	Pods/ plant (#)	100 pods Wt (g)	100 seed wt (g)	2-bean pods (%)	3-bean pods (%)	Yield/5 plants (g)	Yield/ Plot (g)	Yield (ton)/ha
SPS-BL 3	34	10.7	32.7	464	46	37.2	35.0	498	3581	9.4
SPS-Isophenic	30	10.7	31.7	503	49	38.7	25.5	492	3359	8.9
Haruno-Mai	24	9.7	25.7	483	41	34.0	30.5	359	2617	6.9
Sayamusume WCS	45	11.5	24.2	462	48	39.2	13.5	331	2349	6.2
Sayamusume TSC	43	12.0	35.7	555	47	49.2	33.7	635	4487	11.9
Shirofumi	49	14.5	32.0	405	43	47.5	22.5	649	4513	11.9
Beer Friend	38	10.0	27.7	490	39	44.0	16.2	384	2765	7.3
Critical value for differences (CVD)	***15***	***3.7***	***16.2***	***72***	***NA***	***13.5***	***14.2***	***276***	***1896***	***5.0***

Means that differ at least by CVD are different from each other.

Based on a yield of 10 sample plants Sayamusume TSC and Shirofumi at The Sharing Farm produced about 20 tons/ha edamame pods at both spacing but pod quality was better at the wider spacing. A similar response was observed at UBC Farm also but yield/ha was lower because of wider row spacing. This case was different in other varieties which produced higher pod yield/unit area under narrow spacing. The result suggested that plant spacing should be based on variety agro-climate and crop management practices for high yield of better quality. Sayamusume WCS and Beer Friend produced more than 15 percent 1-bean pod type and yielded lower than other varieties though weight of 3-bean type pods was equal to other higher yielding varieties (Table 5, Table 6 and Figure

Figure 13. Pod with 3 bean (left) and bean size in seven varieties of edamame grown at UBC and Sharing Farm in 2013.

Correlations among Traits

Correlations among traits of agronomic importance of edamame grown at The Sharing Farm and UBC Farm are presented in Table 7 and Table 8, respectively. Plant height showed significant positive correlation with number of nodes per plant, pods per plant and 2-bean pod type which was stronger under wide spacing at both locations. But plant height's relation with 3-bean pod type changed to negative and significant under wider spacing at The Sharing Farm.

Table 7. Correlations coefficient (r) between traits measured on edamame grown at Sharing Farm during 2013.

Parameter	Pl.ht (cm)	Node (#)	Branch (#)	Pods/ plant (#)	2-bean pods (%)	3-bean pods (%)	100 pods wt. (gm)	Yield/ plot (gm)
Node (#)	0.75 (0.78)	1.0						
Branch (#)	-0.04 (0.58)	-0.14 (0.83)	1.0					
Pods/plant	0.41 (0.47)	0.45 (0.67)	0.12 (0.80)	1.0				
2-bean pods (%)	0.61 (0.73)	0.70 (0.74)	0.05 (0.67)	0.13 (0.48)	1.0			
3-bean pods (%)	0.47 (-0.67)	-0.55 (-0.63)	0.11 (-0.58)	-0.04 (-0.36)	-0.82 (-0.93)	1.0		
100 pods wt. (gm)	-0.12 (0.25)	0.02 (0.15)	0.14 (0.14)	-0.15 (0.44)	0.30 (-0.11)	-0.01 (0.15)	1.0	
Yield/plot (gm)	0.25 (0.46)	0.41 (0.63)	0.22 (0.65)	0.78 (0.80)	0.16 (0.47)	0.17 (-0.25)	0.23 (0.44)	1.0

Figures outside and inside parenthesis represent narrow and wide spacing, respectively. Figures between 0.34-0.44, 0.45-0.60 and above 0.60 are significant at P= 0.05, 0.01 and 0.001 level, respectively.

Table 8. Correlation coefficient (r) between traits measured on edamame grown at UBC Farm during 2013.

Parameter	Pl.ht (cm)	Node (#)	Branch (#)	Pods/ plant (#)	2-bean pods (%)	3-bean pods (%)	100 pods wt.(gm)	Yield/ Plot (gm)
Node (#)	0.69 (0.82)	1.0						
Branch (#)	0.33 (0.74)	0.72 (0.79)	1.0					
Pods/plant (#)	0.35 (0.70)	0.58 (0.87)	0.73 (0.86)	1.0				
2-bean pods (%)	0.61 (0.53)	0.52 (0.50)	0.43 (0.74)	0.69 (0.61)	1.0			
3-bean pods (%)	-0.30 (0.19)	-0.17 (0.18)	0.25 (-0.02)	0.31 (0.16)	0.13 (-0.00)	1.0		
100 pod wt. (gm)	-0.52 (0.02)	-0.58 (-0.19)	0.20 (-0.18)	-0.36 (-0.32)	-0.13 (0.24)	0.50 (0.09)	1.0	
Yield/plant (gm)	0.15 (0.64)	0.41 (0.63)	0.60 (0.78)	0.82 (0.87)	0.72 (0.73)	0.68 (0.43)	0.06 (0.14)	1.0

Figures outside and inside parenthesis represent narrow and wide spacing, respectively. Figures between 0.34-0.44, 0.45-0.60 and above 0.60 are significant at P= 0.05, 0.01 and 0.001 level, respectively.

However, no relation was exhibited under both spacing at UBC Farm. Weight of 3-bean pod type and yield per plot was not significant with plant height under both spacing at both locations. Nodes per plant, branch per plant, pods per plant, 2-bean pod type and pod yield per plot showed strong positive correlation under both spacing at both locations. Correlation of 3-bean pod type was strongly negative with nodes per plant under both spacing at The Sharing Farm while it was not significant at UBC Farm. Results indicated that correlations between parameters change with the production environment.

Pods per plant showed strong positive correlation with 2-bean pod types and yield per unit area at both locations suggesting that 2-bean pod types contribute more to final yield than 3-bean pod types in this study. Both 2-bean and 3-bean pod types are marketable qualities of edamame. Correlation of 3-bean pod type was negative with pods per plant under wide spacing at The Sharing Farm but contributed almost equally to final yield as of 2-bean pod type. Results of correlation suggested that shorter plant height with more than one branch with many productive nodes are desirable for higher yields of good quality edamame under proper spacing, i.e. 3.5 plants per/ft (30 cm) in rows spaced 45(21") cm apart in Richmond, BC.

Seed Saving

The edamame crop approached physiological maturity from the first week of September. Warm dry weather was required. However, the month of September was wet and relatively cooler which favored foliage and pod disease development. Special attention was given to save seeds under wet weather conditions. Pods that attained physiological maturity were picked from standing plants of early maturing varieties after a few hours of sunshine on occasional sunny days. Pods were kept under room temperature for drying before shelling the beans (Figure 14). Fungus growth on pods was observed, as it could cause seed-borne disease and infect other pods. Plants of late maturing varieties were harvested in the first week of October and hung under a shaded porch for air drying (Figure 15). Pods were threshed when they were dry enough.

Figure 14. Effect of wet weather at maturity on seed saving of edamame 2013.

Figure 15. Alternative indigenous method of air drying pods on plants, seeds and seed size and quality differences observed in edamame grown at two locations (SF=Sharing Farm and UBC Farm) in 2013.

Promotion of Edamame

Based on successful production of a few well- adapted varieties of edamame soybean in Richmond, BC, promotional activities were carried out during 2013. The details are presented in Appendix IV. Distribution of seeds to organic farmers at different agro-climatic pockets of BC was the dominant promotional activity, followed by harvests of fresh edamame pods and distribution to community members for tasting. Fresh edamame pods were also sold at UBC Farm market and the Richmond Farm School market at Steveston village. Fresh harvest pods were also donated to Richmond Food Bank and Richmond Family Place.

The responses were encouraging, as people were happy to find locally grown organic edamame in the market. Home gardeners were eager to learn the skill of successful cultivation of edamame. Organic farmers responded with questions regarding the problems of seed rotting and poor emergence when planted directly in the field. Seed quality and fine-tuned management practices especially for germination, emergence and weed control are important aspects for plant stand establishment. Organic farmers from different pockets of BC who cooperated in the study and promotion had various responses, with the common problem being poor seed germination. A report submitted by Robin Sturley satisfactory yield of well adapted variety in less than three months (Table 9). A high percentage of 2 and 3 bean type pods, a desirable market quality of edamame was obtained at Duncan.

Performance report submitted by organic farmer, Robin Sturley, Duncan BC, was encouraging for high yield of quality edamame in less than three months (Table 9). High percent 2 and 3 bean pods are desirable attributes for high quality of edamame which was obtained at Duncan.

Table 9. Edamame performance in cooperative study conducted at Duncan BC, during summer 2013.

Variety	Days to flower	Maturity days	Plant height cm	Total pods/ five plants	Percent 2 and 3 bean pods
Hakucho	47	79	71	94	89
Sayamusume TSC	50	83	48	90	92
Sayamusume WCS	51	89	58	79	93
SPS-BL 3	51	86	46	122	90
SPS-Isophenic	50	86	50	135	95
Haruno-Mai	55	94	43	114	96

Agro-climatic areas like Duncan BC, could be potential for quality edamame soybean as well as for regional organic seed production. Grand Fork, Abbotsford, Vernon and Kelowna are potential pockets if proper management practices are followed.

DISCUSSION

Vegetable soybean "edamame"(beans on branches) is a crop with rising popularity because of its high nutritional value and eco-friendly soil-enriching properties. Its use has taken many forms, from medicine, staple nutritious food, trendy snack and finally as a food with high nutritive and clinical value for better health of body and mind. It is an ancient crop from Asia, which is still cultivated on rice bunds, thus utilizing waste space to produce nutrient-rich grain while enriching the soil. Its rising popularity and large market demand in Japan and North America, the major importers of edamame, made China and Taiwan major exporters. More than 25, 000 tons of edamame are annually imported into the USA to meet 95% of total market demand. Home gardens and small organic farms are meeting about 5% of domestic demand which are sold primarily at farm markets, as well as some retail stores. A similar case exists in Canada, where demand is rising because of health-conscious Asian immigrants. Locally grown fresh edamame are very limited both in the US and Canada. Realizing the rising demand and good future market opportunities, innovative farmers and scientists in North American universities and government organizations are putting much effort into developing and promoting the production of high quality edamame, with the aim of meeting domestic demand and reducing imports. This is true with all developed countries where health consciousness is increasing with respect to edamame and its cultivation.

The cultivation of edamame soybean is not much different from that of conventional soybean except the fact that green pods should be harvested as vegetables similar to snap beans. Crop stage at harvest is very critical for ensuring bean yield and quality. Marketability of edamame is determined by its physical and organoleptic properties (Masuda 1991). Quality characteristics such as color, texture, pod size, bean/pod and bean size are functions of genotype, environment and development time. Since these quality parameters do not peak at the same time, it is necessary to compromise for proper time of harvest. A hint of pod yellowing is the indication that the pod has begun losing sweetness and accumulating starches that diminish taste and digestibility. In general, the proper stage of harvest is about two weeks before full plant and seed maturity. Shanmugasundaram et al. (1991) suggest the optimum stage of harvest is when pods are still green and tight with fully developed immature green beans. Total harvest period for optimum quality has been reported to be five days.

Vegetable soybean-like conventional soybean can be cultivated by developing varieties adapted to particular agro-climatic conditions. Edamame is now grown on a small scale all over North America. Edamame breeding and promotion activities are carried out in recent years at various U.S universities. Production of organic edamame is in full swing in Virginia to replace tobacco fields. Initiatives in several states aim to boost production, offering US farmers new opportunities to produce a nutritious, good tasting, easy to grow and non-GMO crop. Penn State Extension is working with other universities, USDA and other private industries to introduce U. S developed edamame varieties to the U. S and global market (Altemose, C.A. et al. 2013). Washington State University has done extensive research on variety development and promotion of edamame adapted to the Pacific Northwest region. Sharma and Kshatry (2013) from an adaptation study reported 14 ton/ha yield of high quality organic edamame in Richmond, BC. Agriculture and Agri-Food Canada has developed a new variety of edamame soybean adapted to Ontario's climatic region. Jacob MacKeller's farm near the southwestern Ontario town of Alvinston has become Canada's only commercial supplier of edamame using a locally grown crop (Schaer 2013). The taste of locally produced edamame has added to the already rising demand, and drawing the attention of bigger farmers and industries for commercial cultivation and processing. This has expanded the scope for research and development studies on edamame at research organizations and universities.

Edamame soybean is relatively drought tolerant and adaptive to medium fertility conditions. Luxurious growing conditions may have an adverse effect on reproductive performance unless proper crop management is practiced

(Sharma 2011). Optimum plant spacing, which varies with existing agro-micro-climate, is critical for marketable quality production. High quality seeds, friable, warm, disease-free moist soil, are the primary requirements before planting. Drier, soft, warm, arable and weed-free root zone rich in beneficial micro-organisms are ideal conditions for initial seedling vigor to ensure desirable plant population. Sharma et al. (2013) suggest that wider plant spacing is better than narrow spacing for quality production under Richmond, BC conditions. Crop yields generally fluctuate with year and location, which raises the question of varietal yield stability. Our present study was developed to address these questions and provide pertinent knowledge about the fine-tuned management required for sustainable production of high quality edamame.

Overall, we did not observe much difference in crop performance between two sites that differed in soil type, micro-climate, and field management. Soil textural status at planting in UBC Farm looked much more favorable for germination and seedling emergence. However, varietal response to germination was similar at both locations. Beer Friend and Sayamusume WCS had better germination and emergence compared to other five varieties at both locations which was attributed to better seed saving that resulted in better seed quality. Seed rotting at both locations in other varieties resulted in differences in germination and emergence. This difference must be attributed to differences in degree of fungal seed infection. Dry clay soil on the top 2 inches accompanied by fresh weeds buried underneath resulted in cold and wet conditions at The Sharing Farm. Excess moisture in soil by drip irrigation at UBC Farm was more favorable to fungal growth than to seeds. Well-drained, loose and well-aerated warm soil was needed for the seeds to germinate and emerge. Results of this study supported reports of Sharma et al. (2013) and Miles and Sonde (2001) that seed germination is the consistent problem for attaining proper plant stand. We have observed that seed germination, seedling establishment, proper plant stand and effective weed control at least 35-40 days after planting (DAP) are primary challenges for successful production. Therefore, planting in soil conditions that are more favorable for germination can reduce the cost of both seed and labor, and increase plant stand and uniformity.

Regular plant care against competing weeds followed by sunny days accelerated the vegetative and reproductive growth and development at both locations. Varietal performance for canopy structure, plant height, days to flower and reproductive performance were similar at both locations indicating stability of yield and parameters contributing to yield. High yield of varieties reported by Sharma and Kshatry (2013) from the varietal adaptation study of 2012 was verified by the result of the 2013 study for yield stability. Varieties such as SPS-BL 3, SPS-Isophenic, Sayamusume TSC and Shirofumi showed stability of performance and higher yield irrespective of location. The doubt on seed source reliability raised in 2012 based on plant height and yield differences of the same variety Sayamusume obtained from two sources, West Coast Seed (WCS) and Territorial Seed Company (TSC) were verified from the comparative study at two locations. Sayamusume TSC and WCS grown from the seed produced at The Sharing Farm attended almost same plant height but in 2013 but TSC looked morphologically different and yielded more than WCS at both locations. Additional evidences of notable differences were darker green foliage, relatively late maturity, and a prolonged period for quality pods harvest of Sayamusume TSC compareed to that of Sayamusume WCS. Beer Friend, Sayamusiume WCS, and Haruno-Mai did not yield high in this study. Shirifumi is high yielding with prolonged period for tender pod harvest but is inferior in pod quality such as bean pod type, bean size and attractive green color.

Appropriate plant spacing and plant population are important factors for high quality organic edamame production. Plant spacing within rows determines production capacity of individual plants, depending on soil productivity and crop management including water, weeds, insects and diseases. Wider spacing produced higher quality pods but yielded little lower than the yield from narrow spacing. Therefore, spacing and plant population per unit area of edamame crop should be based on marketable quality and economic viability. Sayamusume TSC and Shirofumi yielded 20 tons/ha at The Sharing Farm while yields of both varieties at UBC Farm was only around 11 tons/ha. This low yield is the result of wider (90 cm) row spacing and significant low plant population at UBC Farm. Narrower row spacing of 45-60 cm with 3-4 plants per ft (30 cm) could produce more than 20 tons/ha under existing nutrient and soil management of UBC Farm. Fresh yield of more than 20 and 10 tons/ha of green pods and green seed, respectively has been recommended has been recommended as benchmark for commercial production in the southeastern US.

Vegetable soybean has an inherent ability to withstand some degree of drought and also compensate thin plant population by branching in order to attain satisfactory level of yield under organic conditions. Wider plant spacing to encourage production of 3-4 productive branches are more desirable than no branching and narrow spacing. High fertility and excessive irrigation should be avoided to control excessive vegetative growth. A well-drained clean field and hot sunny days during the growing season can help the crop mature at least 1-2 weeks earlier than under wet soil conditions. Soil moisture management after the pod-filling stage, therefore, is critical for quality of pods and seed saving. Wet soil prolongs the pod's tenderness and also delays maturity which is not desired for seed saving in Richmond's climate. A drier micro-climate after R5 stage is desirable for quality seed production. The amount of edamame fresh pod yield (11-20 tons/ha) and seed yield (2.6-3.6 tons/ha) was very encouraging, as it exceeded the recommended fresh pod yield of 1lb/3 ft rows required to justify economic viability (Miles et al. 2002).

Based on two years' results, we can advocate the possibility of successful production of organic edamame soybean in different agro-climatic pockets of B.C., especially those drier areas with more sunny days, and more heat units than Richmond. This is supported by a report submitted by Robin Sturley of Duncan, BC who collaborated in the promotion of edamame. Edamame matured in Duncan a week earlier than in Richmond. Late maturing Hakucho and early maturing Haruno-Mai in Richmond matured early and late, respectively in Duncan. Difference in varietal response to maturity suggested a need of developing variety suited to particular region. However, maturity response of Sayamusume, SPS-Isophenic and SPS-BL 3 with high yield and high percent 2 and 3 bean type pod exhibited consistent stability at Duncan. This has suggested the opportunity of developing more stable varieties adapted to wider agro-climatic regions.

A correlation study suggested that about 40 -50 cm tall, locally adapted, early maturing variety with 3-4 productive branches producing more than 88 percent 2 and 3 seeded pods having greater than 35 gm dry seed weight/100 is ideal for quality edamame production in Richmond. Varieties with decreasing suitability for cultivation in Richmond and Vancouver based on this study are: Sayamusume TSC, SPS-BL 3, SPS-Isophenic, Haruno-Mai, Sayamusume WCS, Beer Friend and Shirofumi. First three varieties can be recommended for cultivation based on two years of study. Seed size differences between The Sharing Farm and UBC Farm suggested the possibility of producing bigger size beans with appropriate nutrient and moisture management if market demand is for large beans. It is appropriate and timely for universities and government to start paying attention to organic edamame production to feed the population with nutritious healthy local food while maintaining soil productivity and protecting the environment as a "sustainable food system for food security and nutrition" - the theme of World Food Day 2013.

CONCLUSIONS

Edamame soybean, endowed with multiple benefits from super nutritious food to soil health, is a new crop of commercial importance in North America. Its general ability to grow under a wide range of agro-climatic conditions has opened scope for breeding varieties with specific regional adaptation for higher yield. The rising market demand and popularity has already attracted scientists, industrialists and farmers to consider this as a commercial crop in North America. This is one of the main reasons why American Vegetable Soybean Inc. (AVS) has been established naming Mulberry City of Arkansas "Edamame Capital' of the USA. American Sweet Bean Company in Ohio grows processes and sales 3000-4000 tons of organic edamame. Success of these two initiatives in commercializing edamame has led public and private organizations to focus on research and development of this crop. Agriculture and Agri-Food Canada has developed varieties that could be grown successfully in the Ontario region. Jacob MacKeller in Ontario has been successful in meeting rising demand for locally grown edamame. These emerging efforts have made it possible to read publications entitled "edamame offers good non-GMO opportunities to US farmers".

In general, a drier and sunnier agro-climate is better than a wet and cloudy growing environment. Therefore, the Pacific Northwest region with its cloudy and humid climate is considered not suitable for edamame cultivation. However, the micro-climatic diversity of BC has scope for research and studies to explore the possibility of growing edamame. The last four years of study at The Sharing Farm including varietal adaptation study (OSDP project # I-142) and varietal yield stability study (OSDP project # I-166) have provided the scientific base as evidence for organic production of locally adapted edamame varieties in BC. Varieties like Sayamusume TSC, SPS-BL 3 and SPS-Isophenic adapted well to produce about 20 tons of quality fresh pods per hectare under reduced irrigation without soil amendment. However, the local government's support for its promotion is still lacking because of the fact that government officials and academicians assume that the heat units in BC are not enough for edamame cultivation.

Impressive annual growth rate (20-35%) of the Canadian organic sector and nutritive, environmental and climatic adaptability of organic edamame are driving collective forces to further activities on research, development and promotion of this emerging new crop. Health conscious urban consumers who buy frozen edamame from grocery stores are looking for fresh and locally produced organic edamame. Seed and food leaders of Canada suggest "mainstreaming the production and consumption of 'made in Canada'. Edamame can be one of the ideal crops to fit into the "grow local" and "buy local" initiative of B.C. Organic farmers of BC are slowly moving to include edamame as a potential crop for economic viability as demand for locally produced fresh edamame emerges. Five organic farmers from different agro-climatic pockets of BC cooperated on edamame promotion and experienced common problem in seed germination and seedling establishment. Varieties adapted differently at different pockets with respect to crop phenology and yield suggesting need of locally adapted variety and package of fine-tuned management practice. The following points are critical for edamame growers and promoters;

1. Availability of regionally adapted high quality organic seed.
2. Well drained, moist, warm (12-15 o C), friable, well aerated, moderately fertile soil with pH 6.0 – 6.5 is ideal for good germination and emergence of edamame.
3. First week of June is proper time for planting under defined spacing based on available nutrient and crop management practices.
4. Locally produced quality seeds are needed to ensure intended plant population and marketable quality production.
5. Weed free well aerated root zone is needed for activation of beneficial soil micro-organism to support healthy growth right from germination and seedling emergence.

6. Vigilance to ensure adequate moisture in root zone throughout growing season to optimize vegetative growth and maximize reproductive development is critical for successful production. High fertility and excessive moisture results in poor yield.
7. Plant spacing and crop management should encourage production of 3-4 productive branches maintaining high percent of 2-3 bean type pods. Three to four plants per 30 cm in rows spaced 45-60 cm apart provides the right production environment under medium fertility to yield quality pods even more than 20 tons/ha.
8. Varieties like Sayamusume TSC, SPS- BL 3 and SPS – Isophenic with greater than 88 percent 2 and 3 bean type pods are good for cultivation in Meto-Vancouver region.
9. Some varieties like Sayamusume TSC and SPS-BL 3 have a relatively longer period for harvesting tender green sweet pods than varieties like Beer Friend and Haruno-Mai. The harvest period can be prolonged by management of nutrient and soil moisture accordingly. Availability of adequate soil moisture can significantly increase the size of tender and sweet beans, thus adding market value.
10. Pods should be harvested when the beans fully develop, but are still soft and sweet. Depending on variety, consumers' taste, and market demand, harvesting should be done before pods lose high quality attributes. Hand picking of pods on standing plant, or harvested plant or harvesting plant and leaving pods intact on stem are ways of harvesting depending on choice of producer and consumers.
11. Edamame is an ideal crop to grow without amendment in a field previously planted with heavy feeders like vegetables like carrot, cauliflower, potatoes and salad greens. It will enrich soil productivity for the following crop, cutting down the cost of soil amendment.
12. The initial stakeholders to promote local production and consumption of edamame include the following: small scale family organic farmers, community growers (community supported agriculture), backyard gardeners, food activists, environmental and health conscious eaters, community food centres' organic restaurants, family food retailers and farmers' markets. Government policies and proper incentives for local production of organic edamame are critical.
13. Production and storage of high quality edamame seeds is a challenge in the Pacific Northwest region. However, areas of BC with relatively drier and hotter sunny days like Duncan, Vernon and Grand Forks are more suitable for quality seed production. These farms could be secure sources for production of high quality, locally adapted bio-diverse organic seed for a truly sustainable food system.
14. UBC and Kwantlen Polytechnic University, with academic programs on sustainable agriculture and food systems, should include edamame soybean in their research and development programs.
15. Varieties with diverse genetic backgrounds, (such as SPS-Isophenic, developed by mixing SPS-BL 1 and SPS-BL 2,) should be planted to broaden the genetic base and improve disease and pest management.
16. High quality seed saving of locally adapted varieties for future plantings is central to a sustainable food production system.

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REFERENCES

Alleman,G., C. Miles, and T. Lumpkin. 2000. Edamame for nutrition and health. Farming west of the Cascades Series. Washington State University Extension publication.

Altemose, C.A. et al. 2013. Competing for the U.S edamame market and beyond using U.S edamame varieties and production. National Association of Country Agricultural Agents (NACAA).http://www.nacaa.com/presentations/presentation_list.php?app_id=347

Anonymous 2013. Agriculture and Agri-food Canada. http://www.agr.gc.ca/eng/science-and-innovation/technology-transfer-and-licensing/licensing-opportunities/notice-of-request-for-proposals-2013-varieties/agriculture-and-agri-food-canada-food-type-soybean-lines-available-for-food-quality-evaluation/ox-135-edamame-food-grade-soybean-line/?id=1362660774519

Anonymous. 2012. Vegetable Soybean company to make Mulbery 'edamame capital' of of U. S. Agricultural Communication Services, University of Arkansas. http://arkansasagnews.uark.edu/6583.htm

Anonymous. 2011. Premier's Award for Edamame Grower. (http://www.betterfarming.com/online-news/premier%E2%80%99s-award-edamame-grower-4304).

Anonymous. 2011. Vegetable Research Station field day to feature Edamame. Agricultural Communication Services, University of Arkansas. http://arkansasagnews.uark.edu/6199.htm

Anonymous. 2010. Edamame Nutrition Facts: Your Personal Nutrition Guide. http://www.personal-nutrition-guide.com/edamame-nutrition.html

Anonymous. 2008. American Sweet Bean Company, Ohio. http://www.americansweetbeans
Magee, Elaine 2012. The Secret of Edamame:Edamame:Healthy Soy Snack. http://www.medicinenet.com/script/main/art.asp?articlekey=5628

Anonymous .2005. Frozen Edamame: Global Market Conditions: http://www..avrdc.org/pdf/soybean/frozen%20edamame.pdf

Nair, Sonia. 2010. Edamame Nutritional Value:Buzzle.http://www.buzzle.com/articles/edamame-nutritional-value.html

Anne Egan. 2007. Edamame – Tempting – Featuring – Americas – Vegetable. http://www.amazon.com/EdamameTempting-Featuring-Americas-Vegetable/dp/1579547230

Chase, M. K. 2012. Edamame are tough. Mother Earth. http://www.motherearthnews.com/organic-gardening/edamame-soybean-plants-are-tough.aspx#axzz2dSynYGLf

Ernst, M. and T. Woods. 2001. Marketing challenges for emerging crops in Kentucky: vegetable soybeans. pp. 35-38. In: Second Intl.Veg. Soybean Conf. Tacoma, WA. 10-12 August 2001.

Fushimi, T. and R. Masuda. 2001. 2-Acetyl-1-Pyrroline concentration of the aromatic vegetable soybean" Dadacha-mame". Page 39. In: T.A. Lupkin and S. Shanmugasundaram (eds.) Proc. Second International Vegetable Soybean Conference, Washington State University, Pullman, Washington, USA.

Haas, P.W., L.C. Gilbert, and A.D. Edwards. 1982. Fresh Green soybeans: analysis of field performance and sensory qualities. Rodale, Emmaus.

Hymowitz, T. 1984. Dorset-Morse soybean collection trip to Asia: A 50 year perspective. Econ. Bot. 38:378-88.

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

Konovsky. J., T. A. Lumpkin, and D. McClary. 1994. Edamame: The Vegetable Soybean. http://soybean.uwex.edu/library/soybean/forage/Food_Quality/Edamame-EDAMAME_THE_VEGETABLE_SOYBEAN.htm

Kono, S. 1986. Edamame. Pages 195-243 In, Sakukei o Ikasu Mamerui noTsukurikata. Nosangyoson BunkaKyokai, Tokyo (cited by John Konovsky et al.,1994. Edamame: The Vegetable Soybean.

Kline, W.L. 1980. The effect of intra and inter-row spacing on yield components of vegetable soybeans. MS Thesis, Cornell Univ., Ithaca, NY.

LaSalle, T and P. Hepperly. 2009. Why Organic Farming is a Solution to Global Warming. Rodale Institute.

Lotter D., R. Seidel and W. Liebhardt. 2003. The performance of organic and conventional cropping Systems in an extreme climate year. American Journal of Alternative Agriculture 18(2):1-9.

Lumpkin, T.A. , J.C. Konovsky, K.J. Larson, and D.C. McClary. 1993. Potential New Specialty Crops from Asia; Azuki Bean, Edamame Soybean, and Astragalus. http://www.hort.purdue.edu/newcrop/proceedings1993/v2-045.html#Botany2

Lumpkin, T.A. , J.C. Konovsky, K.J. Larson, and D.C. McClary. 1993. Potential New Specialty Crops from Asia; Azuki Bean, Edamame Soybean, and Astragalus. http://www.hort.purdue.edu/newcrop/proceedings1993/v2-045.html#Botany2

Miles, C. A and M. Sonde. 2002. Edamame Variety Trial. Cooperative Extension, WSU http://vegetables.wsu.edu/EDVarietyReport2002.pdf

Miles, C. A. 2001. Edamame Varietal Trial. Cooperative Extension, WSU http://vegetables.wsu.edu/EDVarietyReport2001.pdf

Miles, C.A., T .A. Lumpkin, and Leslie Zenz. 2000. Edamame. Pacific North West Extension Publication, Washington, Oregon, Idaho. http://cru.cahe.wsu.edu/CEPublications/pnw0525/pnw0525.pdf

Miles, C.A. 2000. Edamame harvesting and marketing potentials. Vegetable Research and Extension, WSU. http//vegetables.wsu.edu/edhrv.html.

Nelson K et. al. 2001. Edamame Soybean Summary. College of Agriculture, Food and Natural Resources. University of Missouri-Columbia. http://aes.missouri.edu/greenley/research/soy1101.stm .

Nuss Jeannie 2013. U.S soybean farmers see growth potential in edamame. http://www.courierpress.com/news/2013/mar/29/us-soybean-farmers-see-growth-potential-edamame/

Schaer, L. 2013. Ontario- farm meeting- rising demand for- locally grown edamame. http://www.farmfoodcare.org/news/news-articles/27-farm-food-care/media/news-releases/2013/309

Shanmugasundaram, S. and M.R. Yan. 2004. Global expansion of high value vegetable soybean. Proceeding VII World Soybean Research Conference-IV International Soybean Processing and Utilization Conference-III Congresso Brasileiro de Soja, Brazil. http://203.64.245.61/fulltext_pdf/eam0087.pdf

Shanmugasundaram, S. 2001. Global extension and diversification of fresh and frozen vegetable soybean. Pages 161-165. In: T.A. Lumpkin and S. Shamugasundaram (ed.) Proc. Second International Vegetable Soybean Conference , Washington State University, Pullman, Washington, USA.

Sharma, K.P and I Kshattry. 2013. Varietal adaptation study to initiate edamame production in Richmond, BC. Report of OSDP Project # I-142 submitted to COABC.

Sharma, K.P. 2012. Organic management that promotes luxurious vegetative growth lowers edamame yield. The proceedings of Canadian Organic science Conference and Science Cluster Strategic Meetings, Winnipeg, Manitoba, February, 21-23, 2012.

Smith, J.M. and F.O. Van Duyne. 1951. Other Soyban products,p.1055-1078. In: K.S> Markley (ed.). Soybeans and soybean products. Vol. 2. Interscience, New York.

United Nations Environmental Programme (UNEP) and United Nations Conference on Trade and Development (UNCTAD), 2008. “Organic Agriculture and Food Security in Africa” pages 1-61.

U.S. Department of Agriculture, Agricultural Research Service. 1998. USDA nutrient database for standard reference, release 12. Nutrient Data Laboratory Home Page, http://www.nal.usda.gov/fnic/foodcomp

Vidal, John. 2013. India’s rice revolution. Global development. http://www.theguardian.com/global-development/2013/feb/16/india-rice-farmers-revolution?view=mobile

Appendix I. Mean value for each trait measured to compare seven varieties of edamame soybean grown at Sharing Farm during 2013.

Traits/Variety	SPS- BL 3		SPS Isophenic		Haruno-Mai		Sayamusum WCS		Sayamusum TSC		Shirofumi		Beer Friend	
Plant spacing	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide
Plants/1.89 m.sq	41	27	33	23	34	26	48	28	36	25	41	26	45	28
Days to flower	52	52	52	52	50	50	52	52	54	54	56	56	54	54
Days pod harvest	94	94	94	94	93	93	96	96	101	101	102	102	95	95
Canopy height (cm)	53	50	46	31	49	33	53	39	48	36	59	48	53	36
Plant height (cm)	34	31	42	27	47	30	51	33	50	37	58	47	53	37
Nodes/ plant	10	10	10	10	10	11	11	11	12	12	13	14	10	10
Branch/plant)	2.1	2.1	2.5	2.4	2.3	2.7	2.3	2.4	2.3	2.8	3.4	4.4	1.5	1.5
Pods/plant	33	38	36	40	36	40	29	34	28	40	39	50	29	32
1-bean pods (%)	12	12	11	11	15	14	17	17	10	12	18	16	18	16
2- bean pods(%)	40	39	41	38	41	42	41	42	50	51	55	56	47	47
3- bean pods(%)	48	49	48	51	44	44	42	41	40	37	27	28	35	37
Yield /10 plants (gm)	843	977	938	1070	886	992	673	823	926	1327	925	1250	644	737
Wt/100 pod (gm)	396	408	394	417	376	378	294	368	470	350	369	381	361	342
Pod yield/plot (gm)	3543	2932	3939	3211	3724	2977	2829	2470	3890	3981	3884	3750	2704	2211
Pod yield/ha (ton)	18.7	15.5	20.8	16.9	19.7	15.7	14.9	13.0	20.5	21.0	20.5	19.8	14.3	11.7
Pods/plant	33.0	37.7	35.3	40.0	36.0	39.7	28.7	34.3	28.3	40.0	38.7	50.0	28.7	31.7

Appendix II. Mean value for each trait measured to compare seven varieties of edamame soybean grown at UBC Farm during 2013.

Traits/Variety	SPS- BL 3		SPS Isophenic		Haruno-Mai		Sayamusum WCS		Sayamusum TSC		Shirofumi		Beer Friend	
Plant spacing	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide
Days to flower	52	52	52	52	50	50	52	52	54	54	56	56	54	54
Days pod harvest	102	102	102	102	102	102	103	103	104	104	110	110	103	103
Canopy height (cm)	56	49	43	55	43	41	73	58	63	61	62	62	62	59
Plant height (cm)	36	32	25	36	24	25	52	39	45	42	52	47	44	33
Nodes/ plant	11	11	10	11	10	10	12	11	11	12	14	14	11	9
Branch/plant)	2.3	2.2	1.9	1.7	2.1	1.6	1.5	2.3	3.4	3.4	4.3	4.2	1.9	1.8
Pods/plant	34	32	28	36	24	28	21	28	33	39	44	60	30	26
1-bean pods (%)	30	26	34	32	22	35	48	47	18	15	36	24	43	24
2- bean pods (%)	35	39	45	34	33	38	38	40	46	53	43	52	40	66
3- bean pods (%)	35	35	21	34	45	27	14	13	36	32	21	24	17	10
Pod yield/5 plants gm)	494	501	410	573	389	328	305	356	566	703	519	778	385	383
Wt/100 pod (gm)	466	462	505	502	510	456	445	480	546	564	394	416	460	520
Pod yield/plot (gm)	4153	3009	3443	3276	3267	1968	2562	2136	4754	4221	4359	4668	3233	2298
Pod yield/ha (ton)	10.9	7.9	9.1	8.6	8.6	5.2	6.7	5.6	12.5	11.1	11.5	12.3	8.5	6.0
Pods/plant	34	32	28	36	24	28	21	28	33	39	44	60	30	26

Appendix III. Record of rainfall, date and intensity of irrigation on edamame crop during, 2013 at The Sharing Farm.

Soil moisture addition date	Source of moisture	Intensity	Crop stage	Effect
May 12-14, 2013	Rainfall	Heavy	Field was not tilled.	Promoted weed growth.
May 22-25, 2013	Rainfall	Medium	Two days after disking the field.	Soil was wet and it delayed soil tilling.
June 18, 2013	Irrigation	Light	V1-V2 stage and poor germination.	Provided soil moisture for gap filling and supported seedling growth.
June 21, 2013	Rainfall	Light shower	Two days after gap filling.	Helped seed germination as well as seed decay.
June 24-25, 2013	Cloud and mist	Very light shower	V2-V3 stage of first and emergence of second planting	Helped emergence of second planting & supported growth
July 19, 2013	Irrigation	Medium heavy overhead	V6-V7 stage of first and V3-V4 stage of second planting.	Supported crop growth after three weeks of dry hot sunny days.
August 2, 2013	Rainfall	Cloud and light shower	R2-R3 stage of first and R1 stage of second planting.	Supported vegetative and reproductive growth and development.
August 4, 2013	Irrigation	Medium heavy overhead	R1-R4 stage and new leaves opening and expansion.	Supported vegetative and reproductive growth and development.
August 11, 2013	Irrigation	Medium light	R4-R5 stage	Saved from drought and supported bean growth.
August 22, 2013	Irrigation	Light overhead	R5 – R6 stage	Helped continue bean growth and development.
August 28-30, 2013	Rainfall	Medium heavy rain	R5-R6 stage	Supported bean expansion.
September, 2-5	Rainfall	Medium heavy	Different stages of physiological maturity	Wet weather & difficulty in seed saving activities.
September 14-15	Rain	Medium	Near seed ripening stage	Delayed seed ripening
Sept 20-23	Rain	Medium	Attaining seed ripening	Delayed ripening & pod wet
Sept 27-30	Rain	Heavy	Seed matured	Caused difficulty in drying
October 1-2	Rain	Light	Late varieties maturing	Caused difficulty harvesting.

Appendix IV. Activities conducted to promote OSDP funded edamame research # I-142 and I-166 in 2013.

Date	Activity	Client	Count	Quantity	Remarks
23-02-2013	Seed donation	Organic farmers-COABC	Varieties 5	1500 gm	Distributed at COABC conference
24-02-2013	Seed donation	Patrick Steiner –Kaslo	Varieties 3	800 gm	Organic farmer, BC
02-03-2013	Seed donation Seedy Saturday	Richmond Food Security Society	Varieties 4	2000 gm	Distributed to community members.
12-03-2013	Seed donation	Roly Russell, Grand Fork, BC	Varieties 7	700 gm	Organic farmers who planted as study.
12-03-2013	Seed donation	Robin Sturley, Duncan, BC	Varieties 6	300 gm	Organic farmer. Has reported positive.
18-03-2013	Seed donation	Allan Surette, Richmond, BC	Varieties 4	460 gm	New organic farmer at Gilmore Steveston.
10-04-2013	Seed donation	Jeremy Pitchfork, Abbosford, BC	Varieties 7	790 gm	Certified organic farmer.
09-04-2013	Seed donation	South Surrey Community garden	Varieties 6	760 gm	Distributed through Gillian Robert.
Aug.-Sept. 2013	Green pods donation	Richmond Food Bank	Varieties 5	Boxes 3	Unlimited for harvest and donation few time
Aug.-Sept. 2013	Market promotion	Richmond Farm School students	Varieties 5	Boxes 2 times	Used for education on marketing skill.
Sept. 2013	Distribution for promotion	Members of CSA at Sharing Farm	Varieties 3	Boxes 4	For tasting fresh organic edamame
Aug.-Sept. 2013	Distribution for tasting	Visitors, farm staff, neighbor and local community	Varieties 5	30-40 samples	Feedback was positive and encouraging.