Varietal Adaptation Study to Initiate Edamame Production in Richmond, BC

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Nature's Path Foods

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EXECUTIVE SUMMARY

Vegetable soybean "edamame" (*Glycine max* L. (Merill.) is an 'emerging new commercial crop' with a fast rising market demand in North America. The high nutritional value, health benefits, and soil health enriching ability of this crop is outstanding. On one hand, the demand in major importing countries; Japan, North America and Europe is increasing. On the other hand, the production cost of edamame in major exporting countries: China and Taiwan is in increasing because of increased labor wage. This will result into increased price and export shortage. This has opened opportunities for production of quality edamame in importing countries where it is not currently cultivated. Health conscious consumers prefer locally-grown, organic fresh edamame over imported frozen products. Grow local and 'buy local' strategies and initiatives inspired varietal adaptation study to initiate edamame production in Richmond, BC.

Six varieties of edamame and a check variety "Black Jet" were planted on May 24, 2012 at The Sharing Farm in Terra Nova Rural Park, Richmond B.C. Six foot long 4 rows spaced 21 inches apart made experimental units which were randomized in three blocks. Efforts were made to maintain a plant spacing of 3-4 inches by gap filling. Composted steer manure was applied and all cultivation practices were organic. Data on growth parameters, disease/pest incidence, fresh pod yield, and seed yield were recorded and analyzed using R statistics. Results indicated that quality seed, friable, moist and warm soil with pH around 6.5 are critical factors for good plant stand establishment. Early seedling disease caused by *Pythium spp*. and leaf injury caused by sun scorch was observed. Insect damage was not seen as a production constraint. Three light irrigations at critical growth stage prevented plants from moisture stress.

Varieties differ significantly for plant stand, plant height, days to flower and days to pod harvest (105-125) and seed dry weight but did not differ for pods/plant, pod type, pod yield and seed yield kg/ha. Differences in inter-plant spacing resulted into plants of various branch types (branchless, one branch, two branches, and three and more branches per plant). Study on branch type indicated that plants with 3-4 branches produced more pods of high quality than less branch types. Varieties Haruno-Mai, SPS-BL 1+2, and SPS-BL 3 matured earlier than Sayamusume. Shirofumi and Hakucho were late with smaller beans than that of others that matured earlier though yield was high. SPS-BL 3, a selection from the Sharing Farm, produced a high percent of 3 bean type pods with large beans (41 g/100 dry seed) and yielded more than 13 tons fresh pods and 2.6 tons seed yield per hectare. A correlation study indicated that plant stand, days to flower, and days to maturity are significant and negative with pod per plant and seed weight. Correlation between pods/plant and 3-beans pod type was significant and positive but it was negative with other pod types. Therefore, early maturity, shorter plant height, proper spacing to produce 3-4 branches/plant, large beans with good flavor and high percent 3 beans type pods are important components of successful production. Heavy biomass of edamame and the increased soil fertility after harvest of the crop as shown by soil analyses was encouraging for sustainable and resilient agriculture. However, locally produced high quality seeds and fine-tuned organic management techniques are the secrets for success.

INTRODUCTION

Soybean (*Glycine max L. Merrill*) "star legume" (UDSA 1998) is one among the most nutritious foods. There are two types of soybean: commodity soybeans harvested as dry beans and vegetable soybeans harvested as green pods. Vegetable soybeans are popularly known as '*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's annual production of 110,000 tons in 1988 which continued to 1992 dropped to 70,000 tons in 2004 (Shanmugasundaram and Yan 2004). An additional 70,000 tons is imported from other countries. Until 1992, Taiwan monopolized the export market to Japan but now 50%, 34%, 13% and 3% of the total export to Japan is made by China, Taiwan, Thailand and other countries including Indonesia, and Vietnam. Japan and USA are two countries making major demand of 87.7% and 11.7% frozen edamame globally (Shamugasundaram 2001).

Soybeans in general are rich in protein, carbohydrates, dietary fiber, omega -3 fatty acids and other micronutrients (Anonymous 2011). Edamame, fat free and full of quality protein and fiber is real "green" food for all, specially the vegans. 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 (prepared) 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, magnesium, folate, vitamins A, B1, B2, B3, C, E and K (Nair 2010). Soybean protein contains isoflavones (phytoestrogens) that reduces bad cholesterol and raises good cholesterol and functions against hypertension, osteoporosis, cancer and heart diseases (Magee 2012).

Vegetable soybean is a large seeded (>30 g/100 seeds dry weight), slightly sweeter type of soybean which are harvested and sold as pods-on-stems, loose pods, or shelled beans. 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. Green edamame pods are boiled or steamed and seasoned with salt and spices. Served cold with a meal or as snack, edamame is eaten by popping the beans from the pod into the mouth. 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*) are occasionally prepared (Lupkin et al. 1993). In Korea, the beans are added to rice and cooked together (*pub mi kong*). Edamame can be found in frozen food section and sometimes in packaged produce of almost any grocery store.

Although production and consumption of vegetable soybean was popular in Japan, Taiwan, China and Korea, some research activities were carried in the United States as early as 1929 (Hymowitz 1984). Research flourished during the 1930s and 1940s because of a protein shortage (Smith and Duyne 1951). A second surge of research began with the interest in organic farming in the 1970s. The Rodale Research

Center, now Rodale Institute, focused edamame research on adaptability and quality (Hass et al. 1982). Basic agronomic research was begun at Cornell (Kline 1980). Washington State University started edamame variety development program from 1995 and has identified varieties suited to the relatively cool growing season of the Pacific Northwest (Miles and Sonde 2002). Today, some home gardeners grow edamame, but there is little commercial production. Therefore, Asian-Americans seeking edamame are usually limited to frozen imports in specialty supermarkets. Through research and development, University of Arkansas has been successful to establish vegetable soybean as emerging new crop in the USA. An industry, American Vegetable Soybean and Edamame Inc (AVS), has been established in the city of Mulbery. The city has been named as '*Edamame capital'* of United States which will receive, process, package and ship Edamame or vegetable soybean grown in Arkansas. AVS targets to meet 12-15% annual rising demand in USA created by increased awareness on the benefit of healthy diets. AVS in long run will export frozen edamame to other parts of the world (Anonymous 2012). Similarly, American Sweet Bean Company in Ohio has been growing edamame since 2005 which is now produces certified organic edamame as sustainable agriculture (Anonymous 2008).

Majority of fruits and vegetables available in urban markets are products of conventional agriculture (agro-chemical intensive and genetically engineered seeds) and transported from long distance away. This truth has raised questions of food mileage, carbon foot print, health risk and urban food security. The health risk imposed from consumption of nonorganic food and increased health care cost is being realized. Conventional farming has also contributed significantly to the climatic crisis of erratic and extreme weather making agriculture more and more unstable and unsecure**.** Edamame, 'emerging new crop' with inherent ability to fix atmospheric nitrogen and enrich soil ecology and fertility can generate income, increase jobs, improve nutrition, and improve the sustainability of soils. 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). It is valuable component in regenerative organic agriculture system which is the life giving medium, the secret source for agricultural quality, productivity, restoration of environmental degradation, and human health through more nutrient dense food (Lotter et al. 2003).

Edamame soybean varieties adaptable to specific local agro-climate can be developed by using available genetic resources. High yielding varieties of edamame adapted to Pacific Northwest have been identified at Washington State University (Miles and Sonde, 2002). Sharma (2012) reported the possibility of growing organic vegetable soybean under medium fertility and reduced irrigation in Richmond, BC. Organic production of fresh pods for niche market adds to food security, better health and environment supporting sustainable food production system. Five year strategic agriculture plan of B. C also focuses on promoting high quality and high value crop for healthy and sustainable future. Therefore, the project was developed with broader goal of introducing edamame soybean as a viable crop in Lower Mainland of B.C with the following specific objectives: i) to evaluate and identify early maturing variety for cultivation under organic conditions adapting to climate change, ii) to determine marketable quality and economic viability for its sustainability, and iii) to share this information and production practices with potential growers to accomplish the goal.

MATERIAL AND METHODS

Research Site and Field Preparation

An area of 110 ft x 35 ft of the East Field of The Sharing Farm within Terra Nova Rural Park, Richmond, B.C was assigned for bean and soybean (edamame) research. The land was dominated by clay silt soil and covered with dense weeds, mainly butter cup, thistle, black berry and grasses. Tall weeds were knocked down on May 13 and the field was tilled on May 15, 2012 using Rotovator (Ground tilling).

Figure 1. Weeds (thistle, butter cup and black berry) were knocked down prior to tilling the land.

Forty five wheel barrow loads of steer manure compost plus 30 kg of dolomite (general purpose dolomite derived from lime stone) was evenly spread over the entire area and power tilled on May 19 and inputs were well mixed with soil in order to create a homogenous soil condition. An area of 1,800 square ft (60 X 30 ft) was demarcated for edamame soybean experimentation (Figure 2). Soil samples were taken before input application and after crop harvest for analysis.

Figure 2. Three blocks are created for edamame soybean varietal adaptation study

Soil Analysis

Soil Sample	pH	Est E.C mmhes Cm	Total organic matter %	Total N %	C/N	Bray available P (ppm)	Available K (ppm)	Available Ca (ppm)	Available Mg Ppm
A	6.3	0.64	6.7	0.25	15.6	178	370	2300	200
B	6.7	0.60	8.9	0.29	17.7	232	465	2650	275

A= Sample taken before manure application: B=Sample taken after crop harvest. Both samples were analyzed in November 22, 2012 at Pacific Soil Analysis Inc., Richmond, BC.

Experimentation

Three blocks of 52 x 6 ft area spaced 2 ft apart were laid out in randomized block design and beds were raised using soil from 2 ft wide inter-block area to facilitate drainage in case of heavy rain during crop season (Figure 2). Each experimental unit was east-west facing, six foot long, with four rows per plot, spaced 21 inches apart. For each variety, experimental units were randomized within the blocks. Seven varieties of edamame, obtained from different sources, (Table 1) were hand planted on May 24, 2012 in 2-3 inch plant spacing. Minimum tilling of wet silt clay had formed small hard clods and every effort was made to keep seed away from clay clods while planting. Sayamusume obtained from West Coast Seeds of B.C. were planted into two rows as North and South borders for comparative observation with Sayamusume obtained from Territorial Seed Company of Oregon. Seed germination and emergence was monitored after a week and seedlings started to emerge on June 9 (17 days after planting). Rows were monitored daily to assist the emerging seedlings until June 15 when seedling stand count was made. Rows with poor seedling stand of five entries except Hakucho and Sayamusume were gap filled on June 17, 2012. Seeds of Hakucho and Sayamusume were all used on first planting.

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

Variety	Source of Seed	Flower and Seed Character
Haruno- Mai	Sharing Farm (Salt Spring Seed)	White –cream flower, medium size seed
SPS-BL- 3	Sharing Farm (Salt Spring Seed)	White flower, large size seed
SPS-BL 1+2	Sharing Farm (Salt Spring Seed)	White flower, medium large size seed
Sayamusume	Territorial Seed Company	White flower, medium size seed- tall plant
Hakucho	Territorial Seed Company	White flower, medium size seed
Shirofumi	Sharing Farm (Anapolis Seed)	White flower, medium size seed
Black Jet	Sharing Farm (Salt Spring Seed)	Purple flower, medium size seed
Sayamusume WC	West Coast Seed	White flower, medium large seeds- short plant

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 3. Seedlings face difficulties to emerge and survive under rough soil and weeds.

All plots were hand hoed and weeded by digging out the strong roots of buried weeds that were emerging and causing damage to weak and tender seedlings (Figure 3). Weeding practice continued until plants attained canopy closing growth in third week of July. Since there was frequent occurrence of rain showers, plants were irrigated only at critical stages of growth if a dry spell was forecasted (Appendix I). Plant growth, development, canopy structure and disease development and insect occurrence were regularly monitored from seedling stage onward. 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 terminal bud) and days to edamame bean harvest were recorded in the field. All plants from the centre two rows of each variety were hand harvested as beans attained full growth and pods were still greenish. Harvested plants were bundled and carried to work room to record data on yield components and fresh pod yield. Yield components (pods/plant, pod types: 1-bean, 2-bean, 3- bean) and plant height was recorded from ten random plants per entry and harvest of whole bundle was recorded as yield of fresh green pods per entry. Data was also recorded to study the relation of branch type on pod production and pod types. Four plants representing four branch types; i) branchless=single stem with no branch ii) one branch= plant with one branch iii) two branch= plants with two branches, and iv) three branch=plants with three and more branches were selected and plant height, pods per plant and pod types was recorded. Remaining two border rows of each entry were left to attain physiological seed maturity. They were hand harvested before rainfall for seed yield estimate and quality seed saving. Special care was taken by drying the pods in a heated room before shelling the pods for seed. All pods were manually picked and threshed by hand when pod reached enough dryness. Seeds were air dried in the room and mold development was prevented. Data on 100 seed dry weight (g) was recorded. Data for pod yield and seed yield were converted to kg per hectare. Edamame promotion was done through different activities as shown in Appendix II.

Data Analyses

We used R software 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. Bi-variate and multivariate relations were checked using Pearson's product-moment correlation Test. Linear regression models were fitted to describe exact relationships between variables if correlation was significant.

RESULTS

Seed Germination and Seedling Establishment

Seed germination and seedling emergence was delayed until June 9 (17 days after planting, DAP) due to wet and cold soil. Seed germination and emergence rating of all entries except Shirofumi and Black Jet ranged from very poor to poor (Table 2). The field was monitored everyday and emerging seedlings were rescued by removing the clay clod hindering the emergence (Figure 4).

Figure 4. Plant stand before emergence of gap filled seeds (top) and seedlings that emerged out against odds (bottom).

Minimum-tilled, wet soil with fresh weeds buried under shallow depth with clods on the surface was not favorable for seed germination and emergence. Most of the seedlings had physical and/or soil borne fungal (*Pythium spp)* disease injury (Figures 3 and 4). The seedlings from the first planting struggled to emerge and survived against all odds to attain a good plant stand. The plant stand was significantly different among varieties (Table 3). Germination and seedlings establishment ranged from a low of 23% to a high of 89% for SPS-BL 3 and Shirofumi, respectively (Table 2).

Seedling count on June 15 (23 DAP) suggested the need to gap fill in order to attain a satisfactory plant stand for yield comparison. However, good rainfall of June 16 softened the soil and helped seedlings emerge from clay clods as revealed by the increase in seedling count the next day. Light rain created soft and ideal soil condition for gap filling. All rows were gap filled as needed on June 17 except rows of Sayamusume and Hakucho because of seed limitation. Gap filled seeds started germinating within a week as a result of warmer soil temperature, and emergence was facilitated by light showers on June 21 and 22 June (Annex I).

Table 2. Mean values for different traits measured in seven varieties of vegetable soybean.

Traits/Varieties	SPS-BL 3	SPS-BL1+2	Haruno-Mai	Sayamusume	Hakucho	Shirofumi	Black Jet
Stand I (#) *	23	80	82	47	51	89	80
Stand II (#) **	71	83	90	55	64	112	89
Flowering (days)	65	66	65	68	74	73	68
Canopy height (cm)	86	79	80	95	98	105	104
Plant height (cm)	55	49	44	60	65	70	80
Total pods/plant (#)	40	29	30	34	44	32	35
Pod yield/10 plants	988	737	689	1057	946	799	600
Pod yield/2 rows (g)	2465(37)	2203(45)	2188(47)	2465(27)	2473(30)	2732(55)	2016(43)
1-bean pods (%)	12	18	16	11	10	12	16
2-bean pods (%)	45	47	50	52	45	51	51
3-bean pods (%)	43	35	34	37	45	37	33
100-seed dry weight(g)	41	37	36	35	29	30	26
Seed yield/2 rows(g)	507(34)	533(38)	510(43)	466(28)	487(34)	512(57)	554(46)
Pod yield (kg)/ha	13044	11658	11577	13046	13088	14458	13044
Seed yield (kg)/ha	2684	2819	2696	2466	2580	2707	2933

***Stand I= Seedling count on first planting (May 24): ** Stand II= Total plant count at harvest. Number within parenthesis indicates the total # of plants harvested from two rows.**

A last count of seedling stand was made on June 30 after thinning of gap filled rows, which is presented as Stand II (Table 2). The crop was manually weeded and hoed, providing soil support to seedlings for proper growth and development on poorly tilled soil (Figure 5). Three rows of variety SPS-BL 1+2 in block number one showed stunted yellowish growth similar to nitrogen deficiency symptoms. However, the sunny and warm days of July speeded up the growth and development of plants, attaining canopy closure after third week of July. The growth differences between plants of first planting and plants of gap filling was noticeable until canopy closing stage (Figure 6).

Figure 5. Three front rows showing stunted plant growth and soil support provided to plants on rows.

Figure 6. Growth differences between plants from first planting and gap filled ones in SPS-BL 3

Diseases and Insects at Vegetative Growth

No disease and insect was identified as a major production threat once seedlings were established. Plants developed mechanisms to control the spread of mechanical, disease or sun burn injury (Figure 7). Cotyledon leaves that were damaged at the beginning of seedling development senesced, preventing further spread of the injury and supported healthy growth in the first trifoliate leaves. The heavy and tender vegetative growth coincided with the beginning of flowering at the last week of July. The scorching hot sun at this stage of crop growth caused sun burn on tender, exposed leaves (Figure 7).

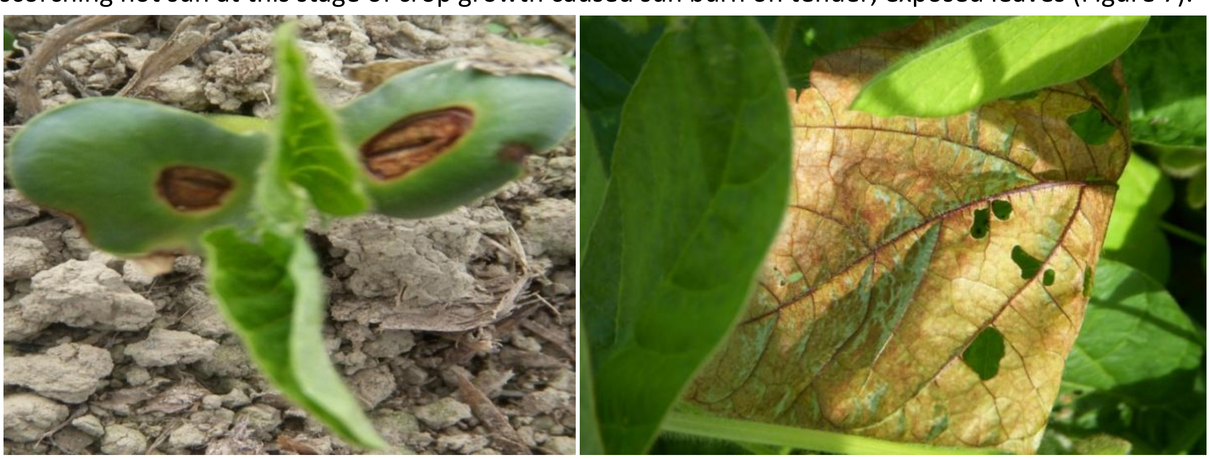

Figure 7. Dead tissues injured cotyledon on the left and injury from sun-burn (bronze color) on the right.

This sunburn which was first observed on July 27 varied in frequency and intensity among varieties .The injury was characterized by up folding of lower veins and development of a bronze color on veins and tissues. This injury continued only for about 4-5 days and did not progress as leaves developed tolerance. Therefore, it was not identified as constraint against successful production.

Figure 8. Insect damages on twigs (left) and leaves (right) of edamame soybean.

Plants were monitored for any kind of insects throughout the growing season, and only a few random plants in the nursery were found damaged by twig borer and leaf feeder (Figure 8). This damage was not seen later as insect predators such as lady beetle were seen to be active on the plants. This natural mechanism for insect control under organic farming benefitted from the rich biodiversity around the border.

Table 3. Analysis of variance of traits that differed in seven varieties of vegetable soybeans grown under organic condition.

Source	df	Plant Stand I	Plant Stand II	Flower DAP	Canopy Ht (cm)	Plant Ht (cm)	100 seed dry Wt (g)	Pod Maturity DAP
Block	2	12.2	69.9	3	68.7	57.6	9.5	0.43
Variety	6	1796.9***	1099.8***	41.6***	349.3***	459.4***	82.3***	139.4***
Residuals	12	48.7	83.0	1.8	22.1	47.6	5.8	1.87
CV		10.8%	11.3%	1.9%	5%	11.4%	7.2%	1.9%

*** Significant at P=0.01 level.

Crop Canopy and Reproductive Development

Flowering began about 50 days after planting (DAP). Days to 50% flowering ranged from 65 days for SPS-BL lines and Haruno-Mai to 74 days for Hakucho (Table 2) exhibiting significant varietal differences for flowering and pod maturity (Table 3). Varieties exhibited significant difference for plant canopy height and plant height (Table 3). Plant canopy height ranged from the shortest of 80 cm for Haruno-Mai to the tallest of 105 cm for Shirofumi (Table 2) observed in Figure 9. Plant height ranged from shortest of 44 cm for Haruno-Mai to the tallest of 80 cm for Black Jet (Table 2).

Figure 9. Edamame crop at seed development and pod filling stage showing differences in plant height, leaf orientation and leaf pigmentation.

Varieties also exhibited significant differences for days to green pods (bean) maturity as well as seed physiological maturity (Tables 2 and 3). Distinct differences in physiological maturity could be seen in the field (Figure 10). SPS-BL 3, SPS-BL 1+2, Haruno-Mai and Black Jet were early maturing (Table 5).

Figure 10. Varietal differences in physiological maturity (top) and pod harvest (bottom) of edamame soybean grown in 2012.

Yield Components and Yield

Yield is a function of the individual plant's production capacity and total productive plants per unit area under a desirable management system. In edamame soybean the yield per plant is determined by total number of pods/plant, number of beans/pod and weight of individual seed. Total plant stand per unit area and branching pattern can compensate for each other to a certain extent. Branch type, in this study showed significant influence in deciding number of pods per plant and pod type (Table 6). However, the interaction between variety and branch type was not significant for 2 bean pod type.

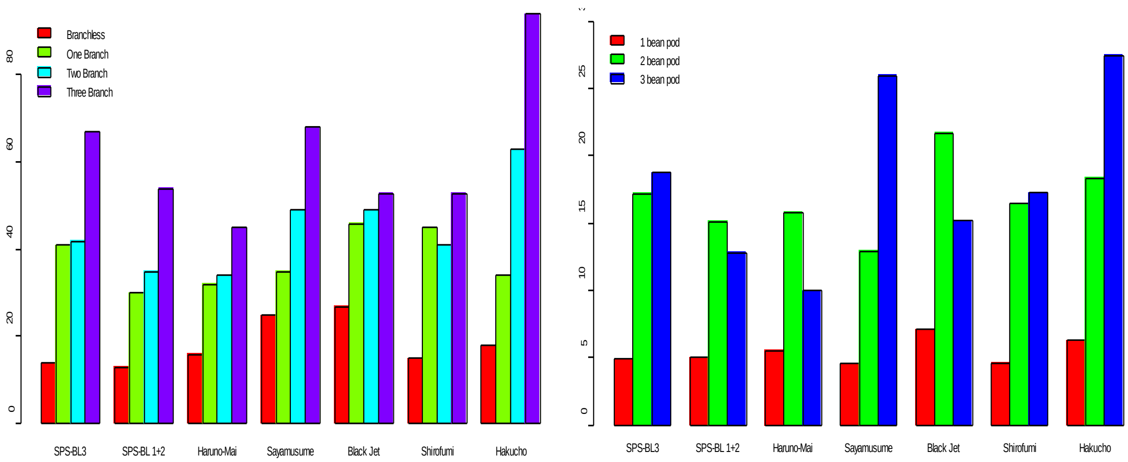

Figure 11. Total number of pods per plant on different branch type (left) and pod type (right) on seven varieties of edamame soybean.

Higher branch type produced more pods than lower branch type in all varieties (Figure 11). Sayamusume, Hakucho and SPS-BL 3 produced high percent of 3 bean type pods while SPS-BL 1+2, Haruno-Mai and Black Jet produced higher percent of 2 bean type pods. Shirofumi produced almost equal proportion of 2 and 3 bean pod type.

Figure 12. Differences in plant morphology, pod bearing feature and pod type in SPS-BL 3, Sayamusume and Haruno-Mai varieties.

Production of 1 bean-type pods was very low in all varieties (Figure 11). Shirofumi and Hakucho produced clusters of pods with either shriveled beans or aborted ovules. This result indicate that branching or no branching does not have much effect on 2 bean type pod production. Enough spacing between plants encouraged better quality edamame with 3 bean pod type and pod yield per plant.

Edamame soybean varieties showed a range from a minimum of 29 to the maximum of 44 pods per plant (Table 2). However, the differences between varieties were not significant with a CV of 3%. Similarly, the differences shown among varieties for three pod types was not significant (Table 4) when varieties were compared though wide range existed (Table 2).

Figure 13. **Differences in plant morphology, pod bearing feature and pod type in SPS-BL 1+2, Shirofumi and Hakucho varieties.**

Table . 4. Analysis of variance for traits except 1 bean pod that did not differ among seven varieties of vegetable soybean grown during 2012.

Source	Df	Total pods/plant	1 bean pods (%)	2 bean pods (%)	3 bean pods (%)	Pod yield Kg/ha	Seed yield Kg/ha
Block	2	20.762	26.000	12.762	43.190	4225613	175476
Variety	6	94.746	161.810*	26.540	65.825	4845680	68945
Residuals	12	47.317.	71.333	21.206	33.635	4023346	66122
CV		3.0%	18.2%	9.5%	15.2%	16.0%	9.5%

There was significant difference in 100 seed dry weight (Table 4) ranging from the lowest of 26 (g) for Black Jet to the highest of 41 (g) for SPS-BL 3 (Table 6). Although varieties under trial differed for plant stand, days to maturity and seed dry weight there was no significant difference among them for fresh green pod yield and dry seed yield (Table 4)

Figure. 15. Seed color, size and morphological differences among seven varieties of edamame under study at Sharing farm, Terra Nova during 2012.

Table 5. Pair-wise means comparisons between traits measured in edamame soybean by Tukey's-Kramer HSD Test.

Variety	Flower DAP	Canopy Ht (cm)	Plant Ht (cm)	Pod maturity DAP	100 seed dry Wt (g)
SPS-BL 3	65 a	86 b	55 bc	111 b	41 a
SPS-BL 1+2	65 a	79 c *	49 bc *	110 b	37 a
Haruno-Mai	65 a	80 c *	44 cd *	110 b	36 a
Sayamusume	68 a	95 a b *	60 b *	118 c *	35 a
Black Jet	68 a	104 a	80 a	105 a	26 b
Shirofumi	73 b	105 a	69 ab	122 d *	30 b
Hakucho	74 b	98 a	64 ab	122 d *	29 b

Note: Means followed by the same letter (s) in common are not significantly different from each other when pair-wise comparison is made P=0.01 level, but means with different letters but sharing * sign are different only at P=0.05 level.

Table 6. Analysis of variance on branch types within variety and interaction on pods and pod types per plant.

Source of variation	df	Mean squares Pods/plant	Mean squares 2 bean pod	Mean squares 3 bean pod
Variety	6	614.4***	90.8*	506.4***
Branch type	3	6822.6***	1394.3***	1272.7***
Variety x Branch type	18	238.4*	45.4	90.9*
Residuals	56	132.8	34.7	46.7

, Significant at P=0.05 and P=0.01 level, respectively.**

Fresh green pod yield per ten plants ranged from a minimum of 600 (g) for Black Jet to maximum of 1057 (g) for Sayamusume followed by 988 (g) for SPS-BL 3 (Table 5). Shirofumi showed the highest pod yield of 2732 (g)/plot which is partly attributed to high plant stand. Although the varieties did not show significant difference in pod and seed yield, it showed quite a range. Pod yield ranged from the lowest of 11577 kg/ha of Haruno-Mai to the highest of 14458 kg/ha of Shirofumi followed by SPS-BL 3 (Table 2). In contrast, seed yield was the lowest of 2466 kg/ha of Sayamusume to the highest of 2933 kg/ha for Black Jet. Overall, SPS-BL 3, SPS-BL 1+2, Haruno-Mai and Sayamusume appeared to be better varieties with respect to days to maturity, fresh pod weight, pod type, and seed dry weight.

Correlations among Traits

The correlation between traits was studied to determine if any significant relation existed between variables. Days to 50% flower, pod maturity, plant height, pod type, and 100 seed dry weight did not show significant correlation with both pod yield and seed yield. However, significant correlation was found between other traits of interest (Table 8). Plant stand and pods/plant showed significant and negative correlation. Days to flower and plant height indicated strong negative correlation with seed weight. Pods/plant exhibited negative correlation with 1 bean and 2 bean pod types while it was significant and positively correlated with 3 bean pod type. Pod yield was negatively correlated with 1 bean pod type but no significant relation was shown with 2 bean and 3 bean pod types. Correlation between 1 bean and 2 bean pod type was not significant but their relation with 3 bean type was negative and highly significant (Table 8). Results suggested that short plant height, early maturity, lower plant stand and high percentage of 3 bean pod type are desirable for higher yield of these varieties in Richmond, which could be achieved by fine tuning crop management. A regression model was developed to explain the relationship between dependent and independent variables (Table 8).

Table. 8. Correlation coefficient (r), regression R-square and model equations to explain relationship between variables measured as: independent (X) and dependent (Y) in edamame soybean.

Independent (X)	Dependent (Y)	Correlation (r)	R-square (%)	Regression model
Plant stand	Pods/plant	-0.45*	21	Y= 49-0.17X
Flower DAP	100-seed dry Wt (g)	-0.67**	45	Y= 99-0.96X
Plant height (cm)	100-seed dry Wt (g)	-0.68***	46	Y= 50-0.27X
Pods/plant	3 beans pod	0.53**	29	Y= 22+0.46X
Pods/plant	2 beans pod	-0.35	12	Y= 56-0.21X
Pods/plant	1 bean pod	-0.53**	28	Y= 22-0.25X
Pod yield (kg)/ha	1 bean pod	-0.50*	25	Y= 16343-286X
1 bean pod	3 beans pod	-0.74***	54	Y= 56-1.36X
2 beans pod	3 beans pod	-.0.85***	73	Y= 99-1.2X

***, **, *** Significant at P=0.05, P=0.01, and P=0.001 levels, respectively.**

Study was also made to determine the relationship of different pod types at different branch types (Table 9). Correlation between I bean type and 2 bean type was not significant for all branch types.

Table 9. Correlations (r) between pod type in different branch type of edamame soybean.

Branch type	Pod type	1 bean pod	2 beans pod
Branchless	2 beans pod	-0.187	
	3 beans pod	-0.486*	-0.887***
0ne branch	2 beans pod	0.032	
	3 beans pod	-0.402	-0.928***
Two branches	2 beans pod	-0214	
	3 beans pod	-0.566*	-0.684***
Three/more branches	2 beans pod	0.071	
	3 beans pod	-0.442	-0.926***
Pooled	2 beans pod	-0.008	
	3 beans pod	-0.478*	-0.875***

***** Significant at P=<0.01 by Pearson's product–moment correlation Test.**

But the correlation of both 1 bean and 2 bean types with 3 bean types was negative and highly significant for all branch types. Results indicated the tendency of increased negative correlation of 3 bean pod type to 1 bean and 2 bean pod types with increasing branch type. This has suggested the need to develop locally-adapted varieties and fine tuned management that could result in an adequate number of branches per plant bearing a high percent of 3 bean type pods for higher pod yield.

DISCUSSION

Vegetable soybean 'edamame' is a crop of multiple values grown in East Asian countries. The first record of its cultivation was in 200 BC in China as medicine (Konovsky et., 1994). It was introduced to Japan from China and its first use was recorded there in 927 A.D. Fresh pod-on-stems are still offered at Buddhist temples. Historically, edamame was grown on the bunds between rice paddies, and this method is still practiced in developing countries like Nepal. Immature soybean seeds are consumed as a vegetable in almost all countries producing soybeans. Selection and cultivation of desirable type (texture and taste) over time resulted in the specialty soybean, the vegetable soybean, or edamame. It is still a minor crop unlike grain-type soybean but its popularity and demand is rising sharply in the world market. Its use has taken all forms from medicine, staple nutritive food, trendy snack and finally as a food with high nutritive and clinical value for better health of body and mind. It is also an eco-friendly crop with an inherent ability to enrich soil fertility and productivity for resilient agriculture. The soil analyses before planting and after harvest show the increase in soil fertility and productivity.

Cultivation of edamame soybean is spreading slowly all over the world which is made possible by breeding varieties adapted to specific regional climates. In general, edamame soybeans are heat-loving, temperature sensitive plants. Temperature sensitive are *summer type*, planted in spring and harvested in 75-100 days. Day-length sensitive are *fall type*, planted in early summer and harvested in 105 days or more (Kono 1986). The relatively cool growing season of the Pacific Northwest is not suitable for growing day-length sensitive edamame soybeans but less photo-sensitive genotypes adapt in this region (Miles and Sonde 2002). Based on seven years of trials they recommended that growers evaluate a variety and seed source for consistency of seed germination, seed emergence, plant stand, and yield potential. Three years of observation for adaptation for organic cultivation of edamame in Richmond showed positive results. The vegetative and reproductive growth under high fertility irrigated and medium fertility rain-fed and/or reduced irrigation indicated that high fertility cultivation practice to be counter- productive for yield (Sharma 2011). These results, as well as the B.C. Agriculture Strategy policy of promoting high quality high value products, prompted us to conduct varietal adaptation experiments.

The experiment was very successful in providing relevant scientific information and opened many avenues for successful production of high quality organic edamame soybean in different agro-climatic pockets of British Columbia. 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. Well drained, loose and warm soil with proper aeration and medium soil fertility with a pH around 6.5 are the desirable soil conditions. Planting on May 24 in wet, cool, clumpy soil with fresh weeds underneath delayed germination and emergence and resulted in poor seedling stand. Significant variation among varieties raised the question of seed quality and genetic ability to germinate and emerge under unfavorable soil conditions. Shirofumi variety exhibited a strong ability to germinate and emerge in contrast to weaker germination and emergence of SPS-BL 3. However, before making varietal comparison for germination, seed viability has to be checked which was not done in this study. Emergence was hindered by crust of clay with small clods and un-decomposed weeds in the vicinity. Our observation supported the report of Miles and Sonde (2001) that seed germination is the consistent problem to attain proper plant stand, though emergence varied significantly among varieties. The dramatic difference in plant height of variety Sayamusume from Territorial Seed Company, Oregon and West Seed Coast in Delta, BC raised questions of seed source reliability. Sayamusume from Territorial Seed was twice as tall as those from West Coast Seed when planted side by side on the same day. Results suggested the need to confirm the proper variety and the origin of the seed.

Poor plant stand could be improved by gap filling after creating a soil environment favorable for germination, but it is labor intensive. Germination of gap filled SPS-BL 3 was twice as much as the first planting, justifying the importance of warm, loose soil with proper soil moisture around the seed. Therefore, planting in soil conditions 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 growth. Plants did not experience moisture stress because of occasional rainfall and supplemental light irrigation at critical stages such as completion of root establishment and branch initiation (20 DAP), one week before beginning of flowering for deciding reproductive structure (about 45 DAP), 60 DAP for fertilization and early bean development, and 75 DAP for tender and plump bean development. The decision to irrigate was based on the weather forecast and soil moisture (Appendix I). Tender leaves (resulting from vigorous vegetative growth) suffered sunburn when exposed to scorching sun. Lack of knowledge about temperature sensitivity of edamame and sunburn injury may cause growers to worry about the possibility of crop failure. However, plants will develop tolerance as tissues get older and the production of new leaves is discouraged.

The distinct variation between varieties in this study in days to flowering suggested the opportunity to select and develop locally adapted varieties. Haruno-Mai and SPS Breeding Lines, followed by Sayamusume produced pods with a more well- developed bean than Shirofumi and Hakucho, though pod maturity between plants within varieties was observed, and can be attributed to plant age difference created by gap filling. Hakucho and Shirofumi had a higher percent of pods containing shriveled seeds and aborted ovules, which can be attributed partly to prolific reproductive capacity and partly to lack of translocation of metabolites to the shaded lower section of the canopy. Black Jet is not a vegetable type soybean and it was used as locally adapted reference variety to determine the degree of adaptation of edamame soybean. Significant difference observed between varieties for plant stand, days to flower, plant height and days to pod maturity was not shown for total pods/plant, pod type (1 bean, 2 bean and 3 bean pod), pod yield and seed yield/ha. Sayamusume and Shirofumi with 27 and 55 plants/12 ft rows produced 1057 (g) and 799 (g) pods/10 plants, respectively. These varieties did not differ in pod and seed yield/ha. The same trend was true with other varieties. Since this result was interesting, effort was made to explore the reason by studying the effect of branch type on pod type and pod yield. Study revealed that increased branching resulted in increased pod production per plant, with no effect on pod type. The pods and beans on plants producing 3-4 branches looked more robust than those produced on branchless plants. Soybean has the ability to a certain degree to compensate for poor plant stand by producing more branches to occupy the canopy space. Branching naturally occurs in thin plant stands and is discouraged in thick plant stands. Care should be taken while deciding plant stand based on prevailing growing conditions. Too thin stands under high fertility conditions may result in longer vegetative growth and a negative effect on reproductive yield. The optimum plant stand desirable for quality edamame production is 3-4 branches.

The level of edamame pod yield (13 tons/ha) and seed yield (2.6 tons/ha) was very encouraging, as it exceeded the recommended yield of 1lb/3 ft rows required to justify economic viability (Miles et al. 2002). Based on these results one can advocate the possibility of successful production of organic edamame soybean in different pockets of B.C., especially those drier areas with more sunny days, and more heat units than Richmond. This is supported by significant and negative correlation of plant stand, days to flower and plant height to yield components and pod yield. Results suggested the true need of developing early maturing, short plants with a high percentage of 2-3 beans per pod. Our observation agreed with another report (Miles and Sonde 2001) that sates that an early maturing variety, fresh and healthy seed, and adequate fertilizer and irrigation are key factors for the successful growing of an edamame crop. In addition, large beans, high percent of 2-3 bean pods, high sugar content, good texture and high yield under local growing condition are desirable qualities (Anonymous 2011). Professor Pengyin Chen at the University of Arkansas has been successful in developing a variety that meets the main flavor requirement of high sugar or sucrose content. The aroma, similar to fragrant Basmati rice, found in Dadachamame, a brown-seeded Japanese edamame has been identified, and the fragrance gene is being transferred to green, yellow and black seeded vegetable soybean (Fushimi et al. 2001). We have also collected black and brown seed color variants from SPS-BL population but other desirable plant characters might have gone undetected. Therefore, there is opportunity to develop suitable variety and feed the world with more nutrients rich food like edamame while protecting the environment and adapting to climate change.

CONCLUSIONS

Edamame soybean appears to be a promising crop for certain agro-climatic pockets of B.C., though no scientific information was available at B.C.'s Ministry of Agriculture and Lands. Academics' general impression about the production of edamame soybean in B.C. is that there are insufficient heat units. However, some organic farmers in Abbotsford (Jeremy Pitchford pers. commun.), Kaslo (Patrick Steiner pers. commun.) and Salt Spring (Dan Jason pers. commun.) grow edamame on a small scale organic farm. Results from this study have encouraged farmers to try edamame as a viable crop and the demand for seed is rising. Impressive annual growth rate (20-35%) of the Canadian organic sector and nutritive, environmental and climatic adaptability of organic edamame soybean together are driving forces to further research and develop activity for this emerging new crop. Loss in quality and nutritive value of edamame is faster than in other vegetables. Therefore, health conscious urban consumers who buy frozen edamame from grocery stores are looking for fresh and locally produced organic edamame. The price of frozen edamame imported mainly from China will rise because of the rising production cost. This is one of the main reasons why Mulberry City has been named 'Edamame Capital' of the USA. American Sweet Bean Company is already producing certified organic edamame and supplying to retail stores. 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 support the "grow local" and "buy local" initiative of B.C.

Based on only one year of scientific study it would be premature to make any scientific recommendations. However, since this study was conducted with a high degree of precision, the following points could be made as conclusion:

1. Vegetable soybeans could be a potential viable crop for better human nutrition, soil health and climate adaptation, if proper varieties and fine-tuned organic management technologies are used.
2. The promising early maturing varieties with quality pods and beans are suitable candidates for cultivation until other superior varieties are developed. Large good-flavored beans with 2-3 beans per pod are desirable qualities of edamame.
3. In addition to a reliable source of locally produced high quality seed, important factors to be considered are proper soil tilth, warm and moist soil, and pH around 6.5.
4. Equally important are marginal soil fertility through quality organic compost, and effective weed control until 35-40 DAP. Excessive vegetative growth results in prolonged growth and low yield.
5. The last week of May to the first week of June is appropriate for planting. Row spacing of 21 inches and plant spacing of 3-4 inches to encourage 2-3 branching is desirable for quality pods and high yield.
6. Pods should be harvested when the beans fully develop, but are still soft and sweet. Depending on variety, consumers' taste, and market demand, harvest should occur before pods lose their green color.
7. The promotion of a market for locally produced organic edamame against imported frozen edamame deserves special attention. The "buy local" initiative fund of the Government of B.C. can be in the wish list.
8. Edamame is an ideal crop to grow near heavy nitrogen feeders such as corn, tomato and cruciferous vegetables, or to rotate into a field previously planted with heavy feeders.
9. 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 farm markets should be the initial stakeholders to promote local production and consumption of edamame.
10. Production and storage of edamame seeds is a challenge in the Pacific Northwest region, due to the generally short growing season. But a secure source of high quality, locally adapted bio-diverse seed is required for a truly sustainable food system. Focal points for local seed production and conservation need to be identified.
11. Some degree of mechanization in its production, processing, and harvest can overcome obstacles to seed production and storage. Seed production in hoop house may be possible.
12. Edamame soybean should be considered as an emerging viable crop by the universities and governments for research and development.
13. For disease and insect management, varieties with diverse genetic backgrounds should be planted, and there is the possibility of developing an isophenic early maturing variety by mixing Haruno-Mai, SPS-BL 3 and SPS-BL 1+2 included in this study.
14. Although these results were obtained from experiment with high precision, additional studies at few locations would be desirable for testing the stability of adaptation and yield.

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Apendix I. Record of rainfall, date and intensity of irrigation on edamame crop during, 2012.

Date of moisture addition on soil	Source of moisture	Intensity	Crop stage	Effect
May 3-6, 2012	Rainfall	Heavy	Field was not tilled.	Promoted weed growth.
June 16, 2012	Rainfall	Medium	Seedling emerging.	Significant help in seedling emergence.
June 21-24, 2012	Rainfall	Very light	Gap filled (June 17) seeds germinating and seedlings growing.	Moist soil promoted seed germination and seedling growth.
July 15, 2012	Irrigation	Light	Branch development and stage to decide on reproductive capacity.	Helped vegetative and reproductive development by avoiding possible moisture stress.
July 20, 2012	Rain	Heavy	Canopy closing and pre-anthesis stage.	Supported active vegetative and reproductive development.
July 29, 2012	Irrigation	Light	Full bloom stage, fertilization and seed filling.	Supported reproductive growth and fertilization and decision for pod type development.
August 15, 2012	Irrigation	Light	Seed development	Supported seed growth by protecting from moisture stress during dry spell.
August 26, 2012	Rain	Light	Bean growth	Helped continue bean growth.
September	No addition	No rain or irrigation	Crops at different stages of maturity	Month long dryspell promoted leaf senescence
October	Rain (113 mm)	Frequent rain whole Momth	Different stages of physiological maturity	Wet weather caused difficulty in seed saving activities.

Appendix II. Efforts and Events of Edamame Promotion Activities at the Sharing Farm

Date	Event	Activities
June-Sept	Field visits several times by students of Richmond Farm School and School Yard Project.	Visited the research site and observe soybean crop at several stages of growth and practices to grow with minimum irrigation organically.
July-Oct.	Regular Informal visits	Terra Nova Rural Park is daily visited by people of various cultural backgrounds and food interest including community gardeners during summer and most of them observed edamame grow successfully and registered interest for seed.
Aug 28	Video Shooting of Documentary	Local TV crew took video of the crop with my interview to make an documentary of urban farming for food security. Edamame crop was the attraction.
Aug 19	Garlic Festival – Regular Yearly Program at Sharing Farm for promotion of activities.	More than 150 people from the crowd of garlic festival visited edamame research and appreciated the efforts success of growing edamame in Richmond climate.
Aug	Raptor Festival – Regular Yearly Program at Terra Nova Rural Park	More than 100 people from the crowd of several hundred visitors observed edamame and registered their interest.
Sep. 20	AAC – Farm Visit	Agricultural Advisory Committee of the City of Richmond organized a Farm Tour for the elected officials of BC, City staffs, representatives of Metro Vancouver cities and farmers who visited Sharing Farm and learned about innovative crop research activities.
Nov 9	BC – Seed Gathering	Thirty participants of the BC-Seed Gathering workshop visited Sharing Farm and were briefed about edamame project and its successful production in Richmond. It was well received.

Project and Expenditure Plan

Reporting Period: May 2012- December 2012 Project #: I-142

Varietal Adaptation Study to Initiate Edamame Production in Richmond, BC

Expenditure Area – Eligible Project Fees and Costs

Expenditure Area – Eligible Project Fees and Costs	Budget Cash costs	Actual to Date Cash Costs
Consultant's Honorarium 250 hrs @$30/hr	7,500	3,575
Field Preparation	550	600
Seed Procurement and Planting	500	542
Local Travel and Supplies	300	439
Conference Participation	500	200
Field days and Communication for Promotion	500	750
Printing	350	519
Total	**10,200**	**6,625**

Karen Dar Woon

Chair

The Sharing Farm Society

Reporting on Project Funding Plan

Reporting Period: May 2012 to March 2013 Project #:I-142

Varietal Adaptation Study to Initiate Edamame production in Richmond, BC

Contribution Sources	Confirmed Y or N	Cash $ to Date	Total Project Cash $	In-Kind Support $	Total Project value
Industry Sources					
The Sharing Farm	Y	2,050	2,050	1,650	3,700
Nature's Path Foods	Y	500	500		500
	Sub-total	2,550	2,550	1,650	4,200
Government Sources	0	0		0	0
Other Sources					
Richmond Food Security Society	Y	500	500		500
	Sub-total	500	500		500
OSDP	Y	3,575	7,150		7,150
	Sub-total	3,575	7,150		7,150
	Total	*6,625*	*10,200*	*1,650*	*11,850*

Karen Dar Woon

Chair

The Sharing Farm Society

BIOMASS, POD AND BEAN OF EDAMAME GROWN AT THE SHARING FARM 2012