Journal of Horticulture

Nolen, et al., J Hortic 2016, 3:1
DOI: 10.4172/2376-0354.1000170

Research Article | Open Access

Increasing Fresh Edamame Bean Supply through Season Extension Techniques

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Received date: Oct 20, 2015; **Accepted date:** Dec 31, 2015; **Published date:** Jan 04, 2016

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Abstract

Soybean [Glycine max (L.) Merr.], a legume native to East Asia contains up to 40% protein and 20% oil. Edamame, a popular vegetable soybean in East Asia, especially China and Japan, harvested at reproductive stages six and seven (R6 or R7) is gaining popularity in the US. Increased awareness of its nutritional quality through promotional campaigns and changing population demographics in the US have led to recent raise in US market demand for edamame. To meet the increasing market demand, frozen edamame from China and Taiwan has been imported. However, the quality of such imported product quickly deteriorates under frozen condition. The objective of this study was to determine whether off-season production systems and staggered planting of different maturity groups (MG) edamame cultivars during the planting season can extend the harvesting window for fresh beans. Four released edamame cultivars of different maturity groups (MG) were used: Gardensoy31 (MG III), Gardensoy41 (MG IV), Mooncake (MG V) and Randolph (MG VI). Total pod yield, marketable pod yield and seed quality traits including protein, oil and sucrose content of each cultivar were determined. The results indicated that early- and mid-spring planting of all MG varieties in the high tunnels allows for pod harvest starting in early July. Planting early in plastic-covered field followed by conventional planting in late-spring allowed harvest in mid-summer through early fall. While total and marketable pod yield differed among cultivars and production systems, seeds had comparable oil content (158 g kg^{-1}) and protein and sucrose content range of 370-422 g kg^{-1} and 33-73 g kg^{-1} on dry matter, respectively. Use of season extension production techniques and soybean of appropriate MG increases harvest window from two weeks to several months.

Keywords: Soybean; Protein; Soil

Introduction

Japanese vegetable soybean (edamame) is harvested at reproductive (R) growth stage six to seven (R6 to R7) when the seeds are still green [1]. At this developmental stage, the seed contains high protein, monounsaturated fatty acids, minerals elements, as well as vitamins like B1 and B2 [2,3]. Edamame, a historically Japanese delicacy has been rapidly incorporated in to American diets due to changing ethnic diversity among US population demographics and increased people's awareness of edamame nutritional qualities. Edamame is currently found in grocery stores and farmers' markets with its demand in the U.S. being estimated at 14,877 tons annually [4,5]. Edamame production is a promising opportunity to meeting the specialty crop market demands. While over 70% of the edamame sold in supermarkets across the U.S is imported from China and Taiwan, it is mainly marketed frozen and this frozen storage conditions lowers its quality drastically. Commercial frozen edamame may contain harmful bacteria such as Escherichia coli and Listeria monocytogenes [6]. In addition, consumers raise the concern of edamame source of safety and start to seek locally grown fresh edamame [7].

Lack of long-term, local supply has become a barrier for successfully marketing of edamame in the U.S because it has a very narrow field harvest window of only a few days. There is very limited information available on extending edamame harvest window though season extension production techniques in Virginia. However, growth studies under plastic film house culture and plastic film tunnel on two Japanese edamame cultivars has been done elsewhere [8]. By planting from February 15 to September 25, they were able to harvest crop from May 25 to December 3. In the US, an intensive research was conducted to extend edamame harvest window in 2003 and 2004 at University of Kentucky [9]. Four Gardensoy series edamame cultivars from MG I to IV were planted in greenhouses and transplanted into the field either covered by plastic film or with no plastic protection on April 1st, 15th, and 29th in Kentucky [9]. The crop was harvested for fresh pods from June 17th (GardenSoy 11, MG I) to August 10th (GardenSoy 41, MG IV). In the study, GardenSoy 11 had lower marketable yield than other cultivars at all transplanting dates, and indication showed that early production by transplanted MG I cultivars may not be successful in Kentucky. Because no research has been done in Mid-Atlantic region to extend fresh edamame harvest window, growers are looking for superior edamame cultivars with high stability and adaptability. There is a possibility for increased on-farm income from edamame related-businesses through off-season supply. To be able to supply fresh edamame for an extended period of time, there is a need for season extension system development.

Materials and Methods

The experiment was carried out for two growing season (2013-2014) at Randolph Research and Demonstration Farm, Virginia State University. The study was laid out as a randomized complete block design with three replications. Four edamame cultivars of different maturity groups (MG) where used: GardenSoy31 (MG III), GardenSoy41 (MG IV), Moon Cake (MG V) and Randolph (MG VI. Edamame planting in early- and mid-spring was done in a high tunnel (a polyethylene-covered semi-circular structure). Planting date varied because of unforeseen weather conditions, however, it was categorized into early-spring (Before April 21th), mid-spring (April 21th-May 21th) and late spring (May 21th-June 21th), and late summer (Aug 21th-Sept 21th). During early and mid-spring planting in the high tunnel, the four edamame cultivars; Gardensoy31, Gardensoy41 and Moon cake Randolph were grown in seed beds covered with a black plastic. During mid-spring planting in the field, edamame was grown in both plastic- covered and non-covered seed beds. Another planting in the field with or without plastic-cover was carried out in late spring. Also in late August-early September, crop was established in the high tunnel to protected crop from cold temperatures later in the fall.

During harvest, all plants were harvested and pods removed. Because cultivars of different MG were planted on the same time, harvesting was sequential. Within a production system, the first to mature were those belonging to the low MG category. Total weight of harvested pods was determined and then sorted into pods with 1, 2, 3 or 4 seeds. The weight of pods in the individual categories was then obtained. Total weight of marketable pods was obtained as weight of all pods with two or more seeds pod^{-1}. A representative sample of the marketable pods was obtained, weighed and shelled. Number of seeds was obtained, and its fresh weight was determined. About 100 gram of the shelled seeds were obtained and stored frozen to await freeze drying. The freeze dried material was ground later and analyzed to determine oil, protein, and sucrose content. Protein content was determined using the combustion method (AOAC - Official Method 990.03) with a Vario MAX CN (Elementar Americas, Inc., Mt. Laurel, NJ, USA) as described by Association of Official Analytical Chemists [10]. Protein factor of 6.25 is used for calculation. Oil was extracted from dried and grounded samples using petroleum ether in an ANKOM XT15 Extractor, Method 2, 01-30-09 (ANKOM Technology, Macedon NJ, USA) as described by AOCS [11] Official Procedure Am 5-04. Sugars were extracted from ground sample (1 g) and analyzed by HPLC following the methods optimized by Johansen et al. [12]. Sugars in the extracts were identified by comparing their retention times with standard sugars. For quantification, trehalose was used as internal standard and the sugar concentration was expressed as g/100 g dry basis. Statistical analyses were carried out using SAS procedures.

Results and Discussion

Plant growth and harvest window extension

Plants grown in high tunnel on plastic covered seed beds in both early- and mid-spring showed good growth. For mid-spring planting, while crop planted in the field on plastic-covered beds showed faster growth than those without plastic cover (Figure 1) and both were slower than that in the high tunnel. Similar use of high tunnels and other season extension techniques have been used in other horticultural crops [13,14] and its beneficial effects is a result of microclimate modification allowing crops to grow outside of their normal time schedule.

Figure 1: Growth in field plants for mid-spring planting with-(a) and without (b) plastic covered seed bed.

For crops grown in early spring, pod harvest was achieved as early as the beginning of July. In early July, Gardensoy31, a MG III vegetable soybean cultivar was harvested and Gardensoy41, MG IV was harvested about two weeks later. At the time of harvest of Gardensoy41 from early-spring planting, Gardensoy31 in the high tunnel from mid-spring planting was ready for harvest. Using the production systems (High tunnel, plastic covered seed- beds in the field, and conventional soybean production) and planting edamame cultivars of different maturity groups simultaneously extended the harvest window from a few days common for conventionally produced crop to several months (Table 1). Within a cultivar, harvesting occurred two weeks to a month between first and second crop in the high tunnel. For the same cultivar in the field, a crop on plastic-covered beds was harvested earlier than those without plastic, because it grew faster and matured earlier. Because of differences in maturity time attributed to planting dates, cultivar's MG, and use of multiple production systems, pod harvest occurred from early July and continued through end of September/ early-October (Table 1). While differences in MG was responsible for harvest time differences among cultivars planted at the same time under a given production system, presence or absence of plastic cover was responsible for differences within a cultivar. In general, Gardensoy31 (MG III) and Gardensoy41 (MG IV) were harvested earlier than Mooncake (MG V) and Randolph (MG VI) when planted at the same time under similar production system. However, extremely cold temperature and animal pest destroyed edamame grown in late summer for two successive years. While this crop was not included in the result, there was a potential to extend harvest into early November.

Pod yield and yield-related traits

For a specific planting period and for a specific production system (high tunnel, field with or without plastic covered seed-bed), total harvested pods differed with edamame cultivars. For early spring planting in the high tunnel, total pod yield varied from 4300 kg ha^{-1} in Gardensoy31 to over 10,000 kg ha^{-1} for Randolph (Table 2). Slightly higher yields were obtained during the second planting in the high tunnel in mid- spring. The increase may be attributed to increased soil and air temperatures that may have allowed for better growth conditions since this was planted 2-3 weeks later in the spring. Yield in a crop established in August and September in the high tunnel are not included due to loss of crops from destruction by Marmota monax (ground hog), an animal pest.

Citation: Nolen S, Zhang B, Kering MK (2016) Increasing Fresh Edamame Bean Supply through Season Extension Techniques. J Hortic 3: 170. doi:10.4172/2376-0354.1000170

Production System	Planting Period	July			Aug			Sept			Oct		
		Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
High tunnel	Early-spring												
	Mid-spring												
Field/Plastic	Mid-spring												
Field/no plastic	Mid-spring												
Conventional	Late- spring												

Table 1: Planting time and harvest period for the different edamame varieties produced under given production systems. Key ____________________Approximate period within which Gadensoy31 and Gardensoy41 where harvested in that order. --------------------- Approximate period within which Mooncake and Randolph where harvested in that order.

Planting period	Cultivar	Harvested pods (kg ha^{-1})	
		Total yield	Marketable yield
Early-spring	Gardensoy31	4373b	2487b
	Gardensoy41	7551ab	3915ab
	Mooncake	9838ab	5020ab
	Randolph	12957a	7506a
Mid-spring	Gardensoy31	6117ab	4120ab
	Gardensoy41	11340ab	6348ab
	Mooncake	10505ab	6053ab
	Randolph	9432ab	6545ab

Table 2: Comparison of total and marketable pod yield for edamame cultivars grown under the high tunnel at different planting dates.

In mid-spring, though not significant, marketable yield from crop established in high tunnels or in the field with plastic covered seed-bed were relatively higher than that from field without plastic cover (Table 3). Overall, Randolph produced relatively high total pod yield than other cultivars within a given production system. In open field for mid-spring planting, Randolph yield range from 14000 to 23000 kg ha^{-1} fresh pods (Table 3). In late spring under conventional planting, Randolph produced the largest (P=0.05) total pod yield of 15850 kg ha^{-1}. The other three varieties produced similar total pod yields averaged at 9900 kg ha^{-1} (Figure 2). The marketable yield for late spring planting ranged from 63 to 77 % of total pod yield depending on variety (Figure 2). The yields for same varieties in this study were lower than those obtained by others in Mississippi [5].While marketable yield for mid-spring planting range from a low of 4120 kg ha^{-1} in Gardensoy31 to 6545 kg ha^{-1} in Randolph under the high tunnel, it ranged from 2092 kg ha^{-1} in Gardensoy31 to 10,814 kg ha^{-1} in Randolph in field grown crop (Table 3 and Figure 2). These values for marketable yield is comparable to those of other vegetable soybean obtained other studies [15,16]. The difference in yield between cultivars within a production system could be attributed to differences in cultivar yield potentials. In field grown crop, plastic covered-bed increased yield in all cultivars. Under all the systems, marketable pods (≥ 2 seeds pod^{-1}) were between 40-75% of the total yield. The number of pods with at least two beans was proportionally higher than the other class categories and could explain the high proportion of marketable pod yield. For all varieties, there was a strong correlation between total and marketable yield (r>0.75) (data not shown). There was also strong correlation (r>0.75) between total pod yield or marketable pod yield and number of pods with one, two, or three seeds.

This would be expected since total yield include all pod while marketable consist of those with ≥ two seeds pod^{-1} and makes sense that as number of these pods in harvest increase, total or marketable yield also increases. Similar correlation has been shown before in other vegetable soybean varieties [17].

The oil content of fresh seed harvested from different production systems and varieties were similar (P-=0.05) and averaged 158 g kg^{-1}

(Table 4). The sucrose content was affected by the interaction of the production system and variety (P<0.05).

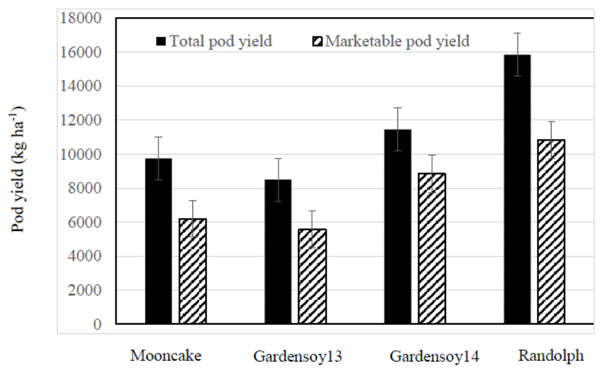

Figure 2: Total and marketable pod yield for crop under conventional planting in late spring. Values are means ± SE.

Production system	Cultivar	Harvested pods (kg ha^{-1})	
		Total yield	Marketable yield
High tunnel	Gardensoy31	6117c	4120cd
	Gardensoy41	11340bc	6348bcd
	Mooncake	10505bc	6053bcd
	Randolph	9432bc	6545bcd
Field/Plastic	Gardensoy31	9732bc	7323bc
	Gardensoy41	8788bc	6110bcd
	Mooncake	10906bc	6947bc
	Randolph	23883a	17522a
Field/no plastic	Gardensoy31	4884c	2092cd
	Gardensoy41	9163bc	5334bcd
	Mooncake	3822bc	822d
	Randolph	14310ab	10287ab

Table 3: Comparison of total and marketable pod yield in edamame cultivars planted in mid- spring using different production systems.

In general, sucrose content was higher for plants seeded later in the field averaging 57 g kg^{-1} across varieties. Across varieties, sucrose content of seed from plants in the high tunnel averaged 43 g kg^{-1}. The protein and oil content of seed in this study were comparable to those reported elsewhere [16,18,19]. While sucrose content were comparable to those reported before [20,21], they are higher than those of vegetable varieties reported in other studies [22]. Seed protein content was affected by interaction of the production system and variety (P<0.05). While there was observed a general increase in seed protein content with time from mid-spring to late-spring in Gardensoy31 and Gardensoy41, there was a reduction in content for Randolph (Table 4). Across production systems, Randolph seed protein content averaged at 396 g kg^{-1} was larger (P=0.05) compared to other varieties.

Production system	Time of Planting	Variety				
		Gardensoy31	Gardensoy41	Mooncake	Randolph	Mean
		____________(g kg^{-1})____________				
		------------Protein------------				
High tunnel	Early-spring	370bB	373bC	377bB	394aAB	378C
High tunnel	Mid-spring	382bB	390bAB	422aA	408aA	401A
Field/Plastic	Mid-spring	375bB	370bC	377bB	401aAB	381C
Field/no plastic	Mid-spring	383aAB	399aA	386aB	390aB	389B
Field/no plastic	Late-spring	397aA	397aAB	374bB	387abB	389B
Mean		381b	386b	387b	396a	
		------------Sucrose------------				
High tunnel	Early-spring	63aA	46bB	33cC	44bB	46B
High tunnel	Mid-spring	37abC	35bC	40abC	45aB	39C
Field/Plastic	Mid-spring	50aB	49aB	39bC	50aAB	47B
Field/no plastic	Mid-spring	59bAB	48cB	73aA	43cB	56A
Field/no plastic	Late-spring	58aAB	59aA	59aB	55aA	58A

Mean	53a	48b	49b	48b	

Table 4: Protein and sucrose content of seeds of edamame cultivars planted at different times and in different production systems. For each seed quality attribute, values in a row followed by same lower case letter are not different (P=0.05), For each seed quality attribute, values in a column followed by same upper case letter are not different (P=0.05).

Conclusions

There is great potential to increase edamame supply in Virginia using season extension techniques. Use of high tunnel and plastic covered seed-beds when ambient conditions are unfavorable for root growth creates localized soil temperatures that allow for improved plant growth. Planted early in the high tunnel, where greenhouse effects increase air temperatures allow early plant growth and early maturity. This crop will be harvested off-season during early summer and producers may access markets when vegetable edamame supply is low and a potential for higher prices exist. A longer period of harvesting time and supply of fresh beans can be achieved with selection of appropriate mix of different MG edamame varieties and production systems. However, economic analysis should be done to determine the viability and profitability of the enterprise that incorporates multiple production techniques. Collaborative work needs to be done with food packaging entities and consumer markets to determine the edamame supply and market demand dynamics so that timely production can be done.

Acknowledgement

We would like to thank the Sustainable Agriculture Research and Extension (SARE) for funding this project. This is a contribution of Virginia State University Agriculture Research Station Journal Article No: 328.

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