Production System for Extending the Harvest Time Frame of Fresh-Market Edamame in Kentucky

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Edamame, a Japanese word now commonly used when referring to pods of a specialty green vegetable soybean [*Glycine max* (L.) Merrill], is harvested as a vegetable when the immature seeds fill 80 – 90% of the pod cavity (slightly before growth stage R6, Konovsky et al., 1994). Edamame is marketed fresh or frozen. The USA accounted for 12% of global consumption but has little production (Lin, 2001). Most edamame in the USA is imported from Taiwan and China and marketed frozen. Fresh edamame is preferred because the quality of edamame rapidly declines in storage; thus there is a high demand for local production. The increase in demand and the lack of a local supply present an opportunity for Kentucky producers to enter the market. Most fresh edamame in Kentucky is marketed through the farmers' market due to the low volume and limited access to post-harvest handling facilities (Ernst and Woods, 2001). Previous research at The National Honan Agricultural Experimental Station in Iksan, Republic of Korea developed a year-round production system (Park et al., 2001). Iksan, South Korea and Lexington, Kentucky have similar climates, so the Korean production system was used as the guide in designing a production system to extend the harvest window for fresh-market edamame in Kentucky.

I. Transplanting for Earlier Harvest

To obtain the higher off-peak prices and be a valued supplier in the market a farmer has to produce an early crop and ensure a continuous supply of fresh produce. Early field planting of edamame in Kentucky is limited by air and soil temperature. With conventional production practices May 1 is the earliest date an edamame crop can be safely seeded in the field, with the crop reaching the harvest stage in mid-August. Production methods which extend the harvest season are often used in vegetable production. Transplants, an integral part of production for many vegetable crops, are used to shorten field production time and to establish a uniform plant stand. Row covers and black plastic mulch help increase the air and soil temperature, while staggered transplanting dates and the use of varieties of different maturity widen the harvest window.

This research evaluated the production of edamame from transplants. We asked the questions: 1) Will row covers allow earlier transplanting and produce an earlier marketable crop with a profitable yield, and 2) Is an increased artificial photoperiod required during transplant production to prevent very early flowering with its accompanying low yield per plant.

Materials and Methods

Replicated experiments were conducted in 2003 and 2004 at the Horticultural Research Farm, Lexington, Kentucky to evaluate the effect of transplanting date, row covers, photoperiod extension during transplant production, and edamame variety maturity on the yield and harvest

date of fresh-market edamame. Four edamame varieties, each of a different maturity group (MG), were grown in 2003: GardenSoy11 (MGI, ~ 106 days to mature seed), GardendenSoy22 (MG II, ~ 116 days to mature seed), GardenSoy31 (MG III, ~ 126 days to mature seed), and GardenSoy41 (MG IV, ~ 136 days to mature seed). In 2004 BeSweet292 (MGI, ~ 100 days to mature seed) replaced GardenSoy11; the other three varieties remained the same. GardenSoy varieties were either obtained from the developer (R.L. Bernard, University of Illinois) or purchased along with BeSweet292 from Rupp Seeds Inc. Wauseon, OH.

Transplant Production

In 2003 transplants were produced in greenhouses with lights set to produce two different day lengths, 14.5 hours and 16 hours light. Day/night temperatures were maintained at 25 ºC/ 21 ºC. In 2004 we produced transplants in greenhouses with either14.5 hours or 18 hours light and day/night temperatures of 25 ºC/ 21 ºC. For a cheaper transplant production system transplants were grown under natural day length (no artificial light) and with lower heat (23 ºC days and 16ºC nights). Prior to planting, seed was inoculated with nitrogen-fixing bacteria *(Bradyrhizobium japonicum)*. A single seed was planted in each cell in a 98-cell plug tray filled with planting media (Promix BX®). Transplanting occurred 21 to 25 days after seeding. The plants were hardened by placing them outside during the daytime for four days prior to transplanting.

Transplant flats

Edamame transplants growing without supplemental light

Field experiment

Plants were transplanted on April 1, 15 and 29 in 2003 and on April 6, 16, and 30 in 2004. These were designated as the early-, mid-, and late-transplanting times.
A custom-made five row drum on a "water-wheel" vegetable transplanting machine was used to punch holes (5" x 5" spacing) in black plastic covered raised beds and to add starter water. The starter water did not contain a starter fertilizer. Transplants were then inserted into the holes by hand. Each plot consisted of 40 plants (5 wide x 8 long). Irrigation was provided by drip tape laid under the black plastic mulch.

Immediately following transplanting half of the plots at each transplanting date were covered by supported row covers made of 1mil transparent plastic film. The ends of the row covers were open during days with temperature > 5ºC. The row covers were removed May 10, 2003 and May 16, 2004 when there was little danger of a spring frost.

Row covers installation over edamame transplants.

An 18 plant sample (3 x 6 plants from the center of each plot) was harvested. Pods were harvested when seeds filled about 80% of the pod cavity without showing yellowing around the developing radicle. Pods were stripped from the plants, and the number of one-, two- or three-seeded pods and the green pod weight were determined. Yields in this report are based on the area harvested from black plastic. The plastic mulch covered only about 50% of the soil area of a field. Thus in a one acre field only 0.5 acre was covered with plastic and available for edamame production.

Edamame transplants growing under row cover.

Results and Discussion

Soybean is a photoperiod sensitive crop. The days to flowering and thus days to maturity is affected by day length. The photoperiod response is also influenced by the temperature. A variety's flowering response to a specific photoperiod and temperature depends on the soybean variety's maturity group. Very early flowering was reported by producer who tried transplanting soybean. Based on this report, as well our previous experience growing soybean in a research greenhouse, we thought day length extension would be necessary to prevent early flowering and its accompanying reduced plant growth and yield. After seeing little value from photoperiod extension in 2003, in 2004 we tried a greater range in photoperiod and also grew a set of transplants in a vegetable transplant production greenhouse with no supplemental lighting and lower level of supplemental heat. While photoperiod significantly affected several growth factors it did not have a significant effect on pod weight or number of marketable pods (Table 1). The remaining data will be presented averaged across daylength-temperature settings in 2003 or for transplant production under natural photoperiod in 2004.

Table 1. Effect of day length and temperature during transplant production on several production factors, 2004 (averaged across varieties, transplanting date and crop protection regime)

Trait	Natural photoperiod 23/16 ºC	14.5 hr photoperiod 25/21 ºC	18.5 hr photoperiod 25/21 ºC
Duration of vegetative growth – days from transplanting to first flower	27	22	32
Green pod weight – g m^{-2}	2340	2240	2310
Marketable pods – 2-seeded + 3 seeded pods m^{-2}	800	780	770

Row covers significantly increased green pod weight and marketable pod production at the early and mid transplant dates in 2003, but row covers were not needed at the last transplanting date (Table 2). April temperatures in 2004 were warm enough that row covers did not significantly increase green pod weight and marketable pods even though they increased plant growth.

Table 2. Effect of row covers and transplanting dates on green pod weight and number of marketable pods averaged across four edamame varieties in the 2003 experiment

Transplanting Time	Green pod weight[#] g m^{-2}		Marketable pods pods m^{-2}	
	Frost protection			
	No protection	Row cover	No protection	Row cover
Early – April 1	681 b*	1128 a	319 b	532 a
Mid – April 15	776 b	1081 a	353 b	505 a
Late – April 29	1289 a	1222 a	579 a	542 a

[#] To convert to lbs 1000 $sqft^{-2}$ divide value by 4.9 (2000 g m^{-2} / 4.9 = 408 lbs 1000 $sqft^{-2}$)
* Values within green pod weight or within marketable pods are compared for the six transplanting dates and row cover combinations. Values among each set of six numbers followed by the same letter are not significantly different (α= 0.05)

The four varieties transplanted on three dates and protected with row covers were harvested during a 37 day period (6/17 to 7/24) in 2003 and a 75 day period (5/27 to 8/10) in 2004 (Table 3). The harvest period in 2004 began 21 days earlier than in 2003 (see BeSweet292 at the early transplanting time) and ended 17 days later (see GardenSoy41 at the late transplanting time). Varieties of four different maturities transplanted on the same date provided a longer harvest period than one variety transplanted on three dates.

Table 3. Date of harvest and duration of harvest periods for transplants grown under row covers

Variety	Date of Harvest*						Duration of harvest (days)	
	Year							
	2003	2004	2003	2004	2003	2004		
	Transplanting Period						Year	
	Early		Mid		Late		2003	2004
GardenSoy11 or BeSweet 292 (MGI)	6/17	5/27	6/29	6/29	7/1	7/2	14	36
GardenSoy22 (MGII)	6/19	7/1	6/24	7/12	7/2	7/2	13	12
GardenSoy31 (MGIII)	7/6	7/4	7/9	6/29	7/23	7/10	17	13
GardenSoy41 (MGIV)	7/6	7/12	7/12	7/23	7/24	8/10	18	24
Duration of harvest (days)	19	46	18	24	23	39		

* Harvest dates from 2003 are averaged across the two photoperiod regimes while dates from 2004 are from transplants produced with the natural photoperiod (no supplemental light).

GardenSoy31 was the highest yielding variety in 2003, but GardenSoy31 was resistant to powdery mildew, which reduced production on the other varieties in 2003. Powdery mildew was controlled in 2004, and we believe the yields are more representative of the varieties from the different maturity groups. BeSweet292, the MGI variety, produced fewer marketable pods and a lower green pod weight at the first two transplanting dates. GardenSoy41 produced the greatest green pod weight at all transplanting dates (Table 4).

Table 4. Marketable pods and green pod weight of four edamame varieties from four different maturity groups (MG) at three transplanting dates in 2004

Transplanting time	Variety (MG)	Marketable pods pods m^{-2}	Green pod weight# g m^{-2}
Early April 6, 2004	BeSweet292 (MGI)	260 f*	790 d
	GardenSoy22 (MGII)	800 bcd	2050 bc
	GardenSoy31 (MGIII)	760 cd	2300 bc
	GardenSoy41(MGIV)	800 bcd	2970 a
Mid April 16, 2004	BeSweet292 (MGI)	560 e	1840 c
	GardenSoy22 (MGII)	970 a	2250 b
	GardenSoy31 (MGIII)	1010 a	2360 b
	GardenSoy41(MGIV)	790 cd	2880 a
Late April 30, 2004	BeSweet292 (MGI)	700 de	2360 b
	GardenSoy22 (MGII)	930 abc	2330 bc
	GardenSoy31 (MGIII)	920 abc	2220 bc
	GardenSoy41(MGIV)	900 abc	3240 a

To convert to lbs 1000 $sqft^{-2}$ divide value by 4.9 (2000 g m^{-2} / 4.9 = 408 lbs 1000 $sqft^{-2}$)
* numbers in a column followed by the same letter are not significantly different (α=0.05)

Recommendations

Edamame production to meet an early market window is feasible in Kentucky using soybean transplants. We recommend producing transplants during this time period without supplemental lighting. Using row covers when transplanting prior to late April will be useful. Unless you have a specific demand for fresh edamame for which you can command a very high premium for early production, early transplanting of a MGI variety does not appear feasible. We recommend transplanting a MGII, MGIII and MGIV variety at your earliest chosen date after April 1 followed by sequential transplanting of a MGIII or MGIV variety until early to mid-May. This should provide a fresh edamame harvest from about June 1 until mid-August when direct seeded edamame may be harvested.

II. Continuous Planting for Summer Production

Providing a continuous supply of fresh edamame to the market is just as important as its presence on the market during the time of inadequate supply and high prices (early and late in the season). To insure the continuity of supply, producers can either use staggered planting dates of varieties of similar maturity or plant at one time a combination of varieties spanning a range of maturities adapted to the location (Bachmann, 2005). Soybean planted in Kentucky between early May and mid-June produces maximum yield, and planting after mid-June reduces yield (Herbek and Bitzer, 1988).

We conducted this study to evaluate the edamame production of varieties differing in maturity when planted across a range of summer planting dates in order to recommend the best continuous planting scheme for fresh-market edamame in Kentucky.

Materials and Methods

A replicated field experiment evaluating the effect of planting date on the yield of edamame soybean varieties from (maturity group) MG I (early maturity), MG II, MG III, and MG IV (late maturity) was conducted in 2003 and 2004 at the University of Kentucky, Horticultural Research Farm, Lexington, KY. Varieties GardenSoy11 (MG I), GardenSoy22 (MG II), GardenSoy31 (MG III) and GardenSoy41 (MG IV) were grown in 2003. Varieties GardenSoy11 (MG I), GardenSoy22 (MG II), BeSweet2001 (MG III) and GardenSoy43 (MG IV) were grown in 2004. GardenSoy varieties were either obtained from the developer (R.L. Bernard, University of Illinois) or purchased along with BeSweet2001 from Rupp Seeds Inc. Wauseon, OH.

The four varieties were planted on six planting dates: May 1, May 15, May 29, June 12, June 26, and July 10 in 2003; and May 6, May 17, May 31, June 15, June 28, and July 13 in 2004. Each plot consisted of five 0.20 m (7.5 in) wide rows, 3 m (10 ft) long. The seeding rate was approximately 24 seeds m^{-1} (7 seeds ft^{-1}) of row. Seeds were inoculated with nitrogen-fixing bacteria *(Bradyrhizobium japonicum)*.

Edamame soybean at six planting dates.

Plants from 76 cm (2.5 ft) of two central rows of each plot were harvested slightly before growth stage R6. Pods were harvested when seeds filled about 80% of the pod cavity without showing yellowing around the developing radicle. Pods were stripped from the plants, and the number of one-, two- or three-seeded pods and the green pod weight were determined. The percentage of marketable pods was calculated as the sum of two and three seeded pods divided by the sum of one-, two- and three-seeded pods.

Results and Discussion

The harvest period from the bi-weekly plantings lasted from August 12 through October 4 in 2003 and August 16 through October 2 in 2004 (Tables 1 and 2). Varieties from earlier maturity groups had wider ranges in harvest dates than varieties from later maturity groups. The duration of the harvest period at each planting date decreased with later planting date. The shorter day lengths later in the growing season caused the narrower harvest window at the later planting dates.

Table 1. Harvest dates of four edamame varieties of different maturity groups at six planting dates in 2003

Variety	Planting date						Duration of harvest period (days)
	May 1	May 15	May 29	June 12	June26	July 10	
	----------Harvest date----------						
GardenSoy11 (MG I)	8/12	8/18	8/24	9/13	9/16	10/4	53
GardenSoy22 (MG II)	8/12	8/18	8/26	9/13	9/18	10/4	53
GardenSoy31 (MG III)	8/22	8/26	9/4	9/13	9/16	10/4	43
GardenSoy41 (MG IV)	8/24	8/26	9/2	9/13	9/18	10/2	39
Duration of harvest period (days)	12	8	9	0	2	2	

Table 2. Harvest dates of four edamame varieties of different maturity groups (MG) at six planting dates in 2004

Variety	Planting date						Duration of harvest period (days)
	May 6	May 17	May 31	June 15	June28	July 13	
	----------Harvest date----------						
GardenSoy11 (MG I)	8/16	8/19	9/3	9/3	9/22	10/2	47
GardenSoy22 (MG II)	8/16	8/21	9/1	9/1	9/22	9/29	44
BeSweet2001 (MG III)	.	8/23	9/2	9/9	9/20	10/2	40
GardenSoy43 (MG IV)	8/23	8/24	9/3	9/9	9/20	10/2	40
Duration of harvest period (days)	7	5	2	8	2	3	

The rate of soybean development from planting through flowering to edamame harvest is controlled by the interaction of photoperiod, temperature, and variety (maturity group specific photoperiod response genes). One can see in Tables 3 and 4 that the days between harvests were not equal even though days between sequential plantings were equal. Later maturing varieties (larger maturity group number) showed less variation in the days between harvests. The standard

deviation is a statistical measure of variability. In both years the standard deviation for days between harvests decreased from MG I through MG IV.

Table 3. Days from harvest of the previous planting date to the harvest of the current planting date for four edamame varieties of different maturity groups (MG) in 2003

Variety	Planting date						Mean	s.d.*
	May 1	May 15	May 29	June 12	June 26	July 10		
GardenSoy11 (MG I)		6	6	20	3	18	10.6	7.8
GardenSoy22 (MG II)		6	8	18	5	16	10.6	6.0
GardenSoy31 (MG III)		4	9	9	3	18	8.6	5.9
GardenSoy41 (MG IV)		2	7	11	5	14	7.8	4.8

* s.d. – standard deviation, a measure of the variability of the values. The larger the s.d. the more variable the days between harvests. All planting dates were 14 days apart.

Table 4. Days from harvest of the previous planting date to the harvest of the current planting date for four edamame varieties of different maturity groups (MG) in 2004

Variety	Planting date						Mean	s.d.*
	May 6	May 17	May 31	June 15	June 28	July 13		
GardenSoy11 (MG I)		3	15	0	18	10	9.2	7.7
GardenSoy22 (MG II)		5	11	0	20	7	8.6	7.5
BeSweet2001 (MG III)			10	7	11	12	10.0	2.2
GardenSoy43 (MG IV)		1	10	6	11	12	8.0	4.5

* s.d. – standard deviation, a measure of the variability of the values. The larger the s.d. the more variable the days between harvests. Planting dates were 13, 14 or15 days apart.

Green pod weight gradually decreased with later planting (Table 5). The gradual decreases added up, however. Compared to the average yield at the three May planting dates, the July planting date yielded 40% less in 2003 and 27% less in 2004. Reduced yields at later planting dates resulted mainly from shorter day lengths and less light energy at later vs. earlier planting dates. The shorter photoperiod also reduced the number of days between planting and flowering and thus accelerated the crop's rate of development. Averaged across the two years, varieties in the different maturity groups produced similar yields: MG I – 1530 g m^{-2} (310 lbs 1000 $sqft^{-2}$), MG II – 1625 g m^{-2} (330 lbs 1000 $sqft^{-2}$), MG III – 1820 g m^{-2} (370 lbs 1000 $sqft^{-2}$), and MG IV – 1680 g m^{-2} (345 lbs 1000 $sqft^{-2}$). The MG III variety yielded significantly more (500 g m^{-2}, a 30% higher yield) than the other three varieties in 2003 but did not yield more in 2004.

One factor important in determining the market value of edamame soybean is the percentage of multiple-seeded pods; a high percentage of multiple–seeded pods is desired. The percent multiple seeded pods differed significantly between years; there were 80% multiple seeded pods in 2003 compared to 65% multiple seeded pods in 2004. Planting date, however, did not affect the percent multiple seeded pods (Table 5).

Table 5. Green pod weight and percent multiple seeded pods (average of four varieties) at six planting dates in 2003 and 2004

Planting date†	Green pod weight (g m^{-2})#		Percent multiple seeded pods	
	Year		Year	
	2003	2004	2003	2004
PD1	1730 c*	1900 a	80	66
PD2	2470 a	1620 ab	85	64
PD3	2130 b	1460 bc	82	65
PD4	1830 b	1570 b	78	64
PD5	1390 d	1500 bc	69	67
PD6	1250 d	1210 c	80	62

* values within a column followed by the same letter are not significantly different (α=0.05)
# To convert to lbs 1000 $sqft^{-2}$ divide value by 4.9 (2000 g m^{-2} / 4.9 = 408 lbs 1000 $sqft^{-2}$)
† 2003: PD1-May 1, PD2-May 15, PD3-May 29, PD4-June 12, PD5-June 26, PD6-July 10
2004: PD1-May 6, PD2-May 17, PD3-May 31, PD4-June 15, PD5-June 28, PD6-July 13

Recommendations

Fresh market edamame can be supplied continuously by first using the transplant production scheme outlined in part I. of this report followed by the direct seeding of soybean at multiple planting dates. Begin planting as close to May 1 as possible. Plant two varieties, one of MG I or MG II and the other of MG III or MG IV at the first planting date then continue planting a MG III or MG IV variety every 14 days until mid-July. This system should provide for a harvest every 7 to 10 days from mid August until early October. Alternatively, if your favorite edamame variety is of MG II or MG I plant that single variety every 14 days after the initial planting date. A variety from maturity groups III or IV, however, will provide more stability for days between harvests.

III. Extending the Fall Harvest Period

In many cases fresh market produce prices rise at the end of the season to levels attained early in the season. Late production of edamame in Kentucky is limited by temperature; the average date of the first frost in most of Kentucky falls between October 10 and 20. The date for a 10% probability of a freezing temperature ($\leq 0^{\circ}$C) ranged from September 22 at Shelbyville, KY to October 15 at Louisville, KY (http://cdo.ncdc.noaa.gov/climatenormals/clim20supp1/states/KY.pdf) High tunnels (plastic covered temporary greenhouses) are utilized to extend fall harvests by protecting plants from low temperatures. This research evaluated the production of late planted edamame under high

tunnels in order to determine the effect and value of high tunnels on October harvest date and edamame yield.

Materials and Methods

Replicated experiments were conducted in 2003 and 2004 at the Horticultural Research Farm, Lexington, Kentucky to assess the effects of high tunnel protection and variety maturity group (MG) on yield and harvest date of late planted fresh-market edamame. Varieties GardenSoy11 (MG I, early maturity), GardenSoy22 (MG II), GardenSoy31 (MG III) and GardenSoy41 (MG IV, late maturity) were grown in 2003. Varieties GardenSoy11 (MG I), GardenSoy22 (MG II), BeSweet2001 (MG III) and GardenSoy43 (MG IV) were grown in 2004. GardenSoy22 produced unacceptable stands in 2004. GardenSoy varieties were either obtained from the developer (R.L. Bernard, University of Illinois) or purchased along with BeSweet2001 from Rupp Seeds Inc. Wauseon, OH.

Seeds were planted July 27, 2003 and July 29 and August 12, 2004. Each plot consisted of five 0.2 m (7.5 in) wide rows, 2.5 m (8 ft) long. The seeding rate was approximately 24 seeds m^{-1} (7 seeds ft^{-1}) of row. Seeds were inoculated with nitrogen-fixing bacteria *(Bradyrhizobium japonicum)*. Half of the plots were covered with high tunnel protection on September 25, 2003 and September 30, 2004, when the low temperature was predicted to reach 5°C. Irrigation was provided through drip tape installed under the plastic tunnel. Lime sulfur at a rate of 63 ml L^{-1} (1 cup $gallon^{-1}$) was applied as needed to control powdery mildew (pathogen *Microsphaera diffusa*). The favorable environment under the tunnel promoted powdery mildew, so plants under the high tunnels were treated more frequently.

Plants from 76 cm (2.5 ft) of two central rows of each plot were harvested slightly before growth stage R6. Pods were harvested when seeds filled about 80% of the pod cavity without showing yellowing around the developing radicle. Pods were stripped from the plants, and the number of one-, two- or three-seeded pods and the green pod weight were determined.

High tunnel construction

Tunnels were constructed using 38 mm PVC tubing, metal foundation posts, 6 mil plastic cover film, and wood side panels with doors and plastic film covering. The high tunnels were 4 m wide and 13 m long with a peak height of 2.2 m. The metal foundation posts holding the 38mm PVC tube half-hoops were placed in the ground 1.5 m apart. The PVC half-hoops were connected by webbing (or rope), and the side panels were installed at opposite ends and tightened to secure the structure. The plastic film was then placed over the structure, and the extra length of plastic on the sides was covered with soil to secure the plastic against the wind. Additional webbing was placed across the width of the completed high tunnel for further wind protection.

High tunnel construction over late planted edamame soybean.

Edamame soybean growing under high tunnel

Yields in this report are based on the area harvested. Each high tunnel required extra ground space to allow for securing the tunnel ends and the cross webbing to tie-down stakes. To calculate yield on a total ground area the yields presented here should be multiplied by the percentage of ground area you crop with your high tunnel installation.

Results and Discussion

2003

Harvest under high tunnels began October 21, 2003 and lasted for four days. Harvest of unprotected plants started two days later and lasted five days (Table 1). High tunnels significantly increased green pod yield from a 3% increase for GardenSoy11 to a 37% increase for GardenSoy41. The MG II variety yielded the most under high tunnels.

Table 1. Harvest date, green pod weight and number of multiple seeded pods of four varieties of different maturity groups (MG) grown with or without high tunnel temperature protection in 2003

Variety	Harvest date		Green pod weight ($g\ m^{-2}$)[#]		Multiple seeded pods ($pods\ m^{-2}$)	
	High tunnel	Not protected	High tunnel	Not protected	High tunnel	Not protected
GardenSoy11 (MG I)	Oct. 21	Oct. 23	1630 c*	1580 c	720 c	665 c
GardenSoy22 (MG II)	Oct. 22	Oct. 24	2010 a	1570 c	845 a	755 c
GardenSoy31 (MG III)	Oct. 21	Oct. 26	1860 b	1500 d	800 b	535 d
GardenSoy41 (MG IV)	Oct. 25	Oct. 28	1890 b	1380 d	630 d	635 d

[#] To convert to lbs 1000 $sqft^{-2}$ divide value by 4.9 (2000 $g\ m^{-2}$ / 4.9 = 408 lbs 1000 $sqft^{-2}$)
* Values within harvest date, within green pod weight or within multiple seeded pods are compared for the eight variety-by-tunnel protection combinations. Values among each set of eight numbers followed by the same letter are not significantly different (α= 0.05). For example, GardenSoy22 produced a greater yield when protected with a high tunnel and yielded more than the other three varieties when grown under a high tunnel.

2004

Within each planting date pods were harvested at nearly the same time for all three varieties, and harvest date was not significantly affected by production under the high tunnels (Table 2). A 14 day delay in planting resulted in a 14 day delay in harvest. High tunnels did not increase yield or number of marketable pods at either planting date, but both yield and pod number were reduced when planting was delayed until August 12 (Table 3). Both the MG I (1120 $g\ m^{-2}$) and MG III (1250 $g\ m^{-2}$) varieties yielded approximately 25% more than the MG IV variety (940 $g\ m^{-2}$).

Table 2. Harvest date of three varieties of different maturity groups (MG) at two planting dates with or without high tunnel temperature protection in 2004

Variety	July 29 planting		August 12 planting	
	High tunnel	Not protected	High tunnel	Not protected
GardenSoy11 (MG I)	Oct. 16	Oct. 16	Nov. 1	Nov. 1
BeSweet2001 (MG III)	Oct. 16	Oct. 16	Nov. 1	Oct. 28
GardenSoy43 (MG IV)	Oct. 16	Oct. 20	Nov. 5	Oct. 28

Table 3. Effect of high tunnel protection on edamame production in 2004

Planting date	High tunnel protection	Green pod weight ($g\ m^{-2}$)[#]	Multiple seeded pods (pods m^{-2})
July 29	High tunnel	1260 a*	510 a
	Not protected	1160 ab	495 a
August 12	High tunnel	1020 ab	395 ab
	Not protected	980 b	335 b

[#] To convert to lbs 1000 $sqft^{-2}$ divide value by 4.9 (2000 g m^{-2} / 4.9 = 408 lbs 1000 $sqft^{-2}$)
* values in a column followed by the same letter are not significantly different α=0.05

Planting edamame in late July until mid August extended the harvest time until November 1. While tunnels increased green pod weight 22% in 2003, their use was unnecessary in 2004 because the lowest temperature before harvest in 2004 was 5°C.

Recommendations

Planting edamame in late July until mid August can extend the harvest time until November 1. The questions are whether high tunnels will be necessary and whether they can be profitable. In Kentucky high tunnels will be necessary in most years to prevent freeze damage to soybean. At the research farm near Lexington, KY, an October temperature ≤ 0°C was not recorded during eight years of the 20 year period 1989-2008 (http://wwwagwx.ca.uky.edu/cgi-public/farm_www.ehtml). The earliest freezing temperature during this period occurred October 8. High tunnels will be necessary in most years for successful October edamame production. The factor determining whether one will use high tunnels will be the price one can command for providing fresh edamame until the end of the farmers' market season. A green pod yield of 2000 g m^{-2} (≈ 400 lbs 1000 sq.ft.$^{-2}$) at a price of \$5 kg^{-1} (≈ \$3 lb^{-1}) was required to cover the production cost of our high tunnel system. This yield level was achieved with only one variety in 2003 with the late July planting date. The 2003 late planted yields, however, were higher than predicted. At the July 27 planting date, yield from the unprotected plots averaged 1500 g m^{-2}. This was higher than the 1250 g m^{-2} harvested from the July 13 planting date (see part II of this series). The progression of decreasing yield due to later planting dates as measured in 2004 (July 13 planting – 1250 g m^{-2}, July 29 planting – 1160 g m^{-2}, August 12 planting - 980 g m^{-2}) appears more probable. Thus, one must command a very high price for fresh late season edamame in order to justify high tunnel production.

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