Virginia Journal of Science
Volume 58, Number 3
Fall 2007

Efficiency of Mechanical Harvest for Immature Vegetable Soybean Pods[1]

Tadesse Mebrahtu[2] and **Chris Mullins**[3],
Virginia State University, Petersburg, VA

ABSTRACT

Since soybean (*Glycine max* [L.] Merr.) is low in saturated fat and active in reducing blood cholesterol, it is gaining interest as a healthy snack food. Direct consumption of vegetable soybeans is very popular in the Orient. However, the cultivars used in Asia are not adapted to U.S. production systems. The objectives of this study were to determine the efficiency of mechanical harvest and to identify vegetable soybean cultivars adapted for a mechanical harvest system. To implement the objectives, four vegetable soybean cultivars were planted in a randomized complete block design at Randolph Research Farm, Virginia State University. The cultivars were hand harvested and mechanically harvested at the green pod stage and evaluated for green pod yield (kg ha^{-1}), one hundred pod weight (g), plant height (cm), and pod dimensions of length (cm), width (cm), and thickness (cm). A significant difference ($P < 0.01$) was observed among the two methods of harvesting. The hand harvested beans yielded twice as many more pods as the mechanical harvested beans. However, the pods harvested mechanically were cleaner and required no further cleaning as compared to hand harvested pods. There was also significant cultivar x method harvest interaction. The common bean picker was effective in harvesting the vegetable soybean cultivars with plant height of 55 to 66 cm and pod size that ranged from 128 to 144 g 100^{-1} pods This type of operation could be easily adapted by farmers using appropriate cultivars.

Key words: Vegetable soybean, cultivars, harvesting, mechanical, weight, yield, edamame

INTRODUCTION

In the United States (U.S.), an interest in healthier food is a driving force in the search for nutritious alternative crops. A quarter of the U.S. population has elevated cholesterol levels, a condition associated with a high risk of heart disease (Roberts, 1987). Many Americans are interested in consuming foods that lower blood cholesterol

---

1 Contribution from Agricultural Research Station of Virginia State Univ. Journal Series No. 257. The use of any names and /or vendors does not imply approval to the exclusion of the other products or vendors that may also be suitable.

2 Correspondence should be addressed: Tadesse Mebrahtu, Professor/Soybean Breeder Agricultural Research Station, Virginia State University, P. O. Box 9061, Petersburg, VA, 23806. E-mail address: (tmebraht@vsu.edu).

3 Horticulture Research Specialist, Cooperative Extension, Virginia State University, P. O. Box 9081, Petersburg, VA 23806 (cmullins@vsu.edu).

level. Among alternative vegetable crops, soybean has the distinction of being low in saturated fat and active in reducing blood cholesterol level. In addition, the Food and Drug Administration (1999) has approved the claim for the cholesterol lowering effect of soybean (*Glycine max* [L.] Merr.). Health benefits associated with soybean consumption include a cholesterol-free source of protein and lower intake of saturated fat. Several studies have shown a relationship between soy food consumption and the prevention of heart disease and cancer (Carroll and Kurowska, 1995; Kritchevsky, 1994; Potter, 1994). The announcement by FDA that soybean could lower the risk of heart disease further spurred the demand for frozen vegetable soybean. Educating the consumers with preparation, cooking, and consumption methods, and developing better flavor and quality varieties are very important for a dramatic increase in demand. The aging baby boomer generation is concerned with longevity and the prevention of chronic diseases. As a result, they seek functional foods such as soybeans including vegetable soybeans for healthy benefits.

Vegetable soybean or edamame is one potential crop that can bring economic benefits to the farmers. What makes vegetable soybean a new phenomenon is the snack itself, and the broader acceptance as an ingredient in cooking. Like all soybeans, vegetable soybeans are versatile: they can be served as a fresh cooked vegetable, included in salads, and roasted (Mebrahtu et al., 2005a, b). Generally, vegetable soybean is a large seeded variety harvested when the pods are fully filled but still green (Shanmugasundaram et al., 1991; Mebrahtu et al., 2005a,b). Vegetable soybean has a sweet and delicious taste, and can be eaten as a snack either boiled in water or roasted (Liu, 1999). The fresh beans can also be mixed into salads, stir-fried, or combined with mixed vegetables. Vegetable soybean is also used to make tofu, ice cream, and similar desert items (Shanmugasundaram et al., 1997).

Vegetable soybean is a new crop for most Virginia farmers and mechanical harvesting is essential to make edamame a profitable and manageable crop for large scale production. Silbernagel et al. (1991) reported that machine-harvest of common beans requires a uniform maturation where the majority of the pods are ready at the same time for once-over destructive harvest. Moreover, the best machine-harvested cultivars bear the pods in the mid to upper part of a sturdy upright plant. This allows for the highest pod yields.

There are three major constraints to large-scale vegetable soybean production in the U.S. First there is a lack of adapted vegetable soybean cultivars that are suitable as a vegetable crop. Cultivars currently grown in a small production system are of Japanese origin, and are less adapted to U.S. environmental conditions. Second, there are no efficient ways to harvest and shell vegetable soybean pods. The current operation is labor intensive and not economically attractive. Finally, there is a wide knowledge gap in vegetable soybean food processing and utilization.

For adaptation of edamame as a specialty crop, it is imperative to identify vegetable soybean cultivars that possess desirable agronomic and architectural traits for machine harvest. The objectives of this study were to: 1) determine the efficiency of mechanical harvest for immature vegetable soybean pods and 2) identify vegetable soybean cultivars that are suitable to mechanical harvesting.

MATERIALS AND METHODS

Four potential cultivars, 'Kahala', 'Kanrich', 'Owens', and 'Asmara' from maturity groups (MGs) III, IV, V, and VI, respectively, were planted in four-row plots, in a randomized complete block design (RCBD) with three replications on Abell sandy loam (aquatic Hapridults, fine loamy mixed, thermic), at Randolph Research Farm of Virginia State University, Petersburg, Va during the 2002, 2003, and 2004 growing seasons. Each four-row plot was 60 m x 3 m long, with a spacing of 75 cm between rows and a seeding rate of 23 seeds m^{-1}. Conventional tillage practices were used, and fertilizer was applied following soil test recommendations. Trifluralin herbicide (Treflan HFB, manufactured by DOW, Agro Sciences, LLC, Indianapolis, Ind) was pre plant incorporated into the soil at the recommended rate of 0.56 kg *a.i*/ha to control weeds.

Harvest and Data Collection

Each cultivar was harvested mechanically with a common bean picker (Pixall BH 100, OXBO, Clear Lake, WI) when plants reached an immature bean stage (R6-R7, Fehr et al., 1971) and expanded to fill 80 to 90 % of the pod width. At the time of mechanical harvest, whole plants from a 1.5 m x 3.0 m section were harvested and placed in a plastic bag and brought immediately to the laboratory where pods were removed by hand, weighed and presented as green pod yield (kg ha^{-1}). One-hundred pods were taken at random and weighed and presented as g 100^{-1} pods. Ten pods taken at random from the harvested plots were measured (length, width, and thickness) as described by Frank and Fehr (1981) and were presented in cm. Plant height, from ten randomly selected plants were measured in cm.

Experimental Design and Data Analysis.

Data from each year were analyzed separately as a randomized complete block by the Statistical Analysis System Package (SAS, 2001). The homogeneity of error variances were tested before data were combined over years. Cultivars and method of harvest were considered as fixed effects and years as random effects. Year effect was tested for significance using replication within year [rep (y)] as the error term, cultivar effect was tested using the cultivar x year interaction (CYI) as the error term and CYI was tested using the pooled error term. Means were separated via the least significant difference (LSD) procedure at the 5% probability level as described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

The growing conditions during this study varied from year to year. In general, there was sufficient moisture needed for productive plant growth in 2002, 2003 and 2004 growing seasons (Table 1). However, in the 2002 growing season, there was severe drought and higher temperatures during the early pod filling stage.

The combined mean squares analyses for agronomic parameters are presented in Tables 2 and 3. There were significant differences ($P < 0.01$) among years for green pod yield, plant height, one - hundred pod weight, pod length, and pod width. The cultivar and cultivar x year interaction (CYI) effects were significant ($P < 0.01$) for all traits except pod thickness. The significant CYIs suggested the performance of the

TABLE 1. Mean of maximum temperature, minimum temperature, and rainfall for 2002, 2003, and 2004 growing seasons.

Month	Mean Maximum Temp. (C⁰)			Mean Minimum Temp. (C⁰)			Mean Rainfall (cm)		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
May	27.2	24.1	27.7	14.6	12.7	16.7	7.29	14.94	10.87
June	33.4	28.4	28.7	16.0	17.0	18.4	6.22	14.86	18.21
July	34.7	30.5	31.0	21.8	20.4	21.1	5.89	14.45	16.99
August	34.0	31.3	28.8	23.6	21.1	19.1	12.07	18.24	24.31
September	29.1	26.5	26.8	20.2	16.2	16.3	4.9	33.27	21.97

TABLE 2. Mean square analysis of variance of green pod yield and plant height of four vegetable soybean cultivars.

Source of variation	df	Green pod yield	Plant height
Year (Y)	2	280131983.5**	19601.7**
Rep[Y]	6	466185.4	40.45
Method (METH)	1	548863994.1	29.90
METH*Y	2	121056135.7**	117.99*
REP(Y)*METH	12	792200.9	27.66
Cultivar (C)	3	14528587.7**	6302.91**
C x Y	6	17792263.0**	468.50**
C x METH	3	21969072.8**	69.13
C x Y x METH	6	4900778.3**	21.29
Pooled error	30	2156898.4	44.86

*, ** Significantly different at the 0.05 and 0.01 probability levels, respectively.

cultivars was not consistent from one growing season to another, and multiple-year testing is required. Among the traits studied, green pod yield and pod width had significant cultivar x method, and cultivar x year x method interactions.

The overall genotypic green pod yield mean was 8831 kg ha^{-1} and ranged from 7559 kg ha^{-1} for Kanrich to 9651 kg ha^{-1} for Owens. None of the cultivars tested produced significantly higher mean green pod yield than the overall green pod mean (Table 4).

The overall plant height mean for the cultivars was 75 cm. Owens had the shortest, while Kahala and Kanrich had the tallest mean plant heights. These two cultivars,

TABLE 3. Mean square analysis of variance of hundred pod weight, pod length, pod width and pod thickness.

Source of variation	df	Hundred Pod weight	Pod length	Pod width	Pod thickness
Year (Y)	2	4490.51**	120.01**	2.86**	21.46
Rep[Y]	6	73.47	5.39	0.18	19.88
Method (METH)	1	333.68	0.13	0.20	26.28
METH*Y	2	230.93	0.13	0.20	26.28
REP(Y)*METH	12	71.81	2.94	0.12	20.28
Cultivar (C)	3	6888.94**	319.50**	16.08**	38.69
C x Y	6	1705.05**	51.83**	1.24**	39.44
C x METH	3	58.68	0.50	0.23**	21.58
C x Y x METH	6	44.88	0.50	0.23**	21.58
Pooled error	30	44.18	2.23	0.04	22.38

TABLE 4. Mean of four vegetable soybean cultivars averaged over three growing seasons, three replications, and two harvesting methods.

Cultivars	Green pod yield (kgha^{-1})	Plant height (cm)	Hundred Pod weight (g)	Pod length (cm)	Pod width (cm)
Kahala	9177	81	97	4.3	0.90
Kanrich	7559	98	127	4.9	1.14
Owens	9651	55	144	5.3	1.06
Asmara	8938	67	128	4.9	1.06
Means	8831	75	124	4.9	1.00
LSD $_{(0.05)}$	831	4	4	0.1	0.01
CV %	17	9	5	3	2

Kahala and Kanrich also had the lowest hundred pod weight and pod length means. While Asmara and Owens had the highest hundred pod weight and pod length means.

There was also significant cultivar x year interaction. The overall green pod yield mean in the 2003 growing season was higher than both the 2002 and 2004 growing seasons (Table 5). Kahala produced higher green pod yield than the overall means of 2002 and 2004 growing seasons. While Owens produced higher green pod yield than the overall green pod yield means of 2003 and 2004. Kahala and Kanrich were the cultivars that had consistently taller plant height in all three growing seasons. Owens

TABLE 5. Mean of green pod yield, plant height, hundred pod weight, pod length, and pod width of four vegetable soybean cultivars for each three growing seasons (2002, 2003, and 2004).

Cultivar	Green pod yield (kg ha^{-1})			Plant height (cm)			Hundred pod weight (g)			Pod length (cm)			Pod width (cm)		
	2002	2003	2004	2002	2003	2004	2002	2003	2004	2002	2003	2004	2002	2003	2004
Kahala	7710	11038	8782	54	95	96	120	91	80	4.3	4.5	4.2	0.89	0.95	0.91
Kanrich	5343	12034	5300	57	106	133	143	132	106	5.3	4.8	4.8	1.20	1.10	1.13
Owens	4721	13627	10607	29	68	69	159	130	143	5.4	5.0	5.6	1.10	0.99	1.10
Asmara	5853	13647	7314	34	79	88	135	101	147	5.5	4.5	4.8	1.10	0.99	1.10
Mean	5907	12586	8001	43	87	96	139	114	114	5.1	4.7	4.8	1.11	1.01	1.01

consistently had lower mean plant height than the overall means of each of the three growing seasons, and also had a higher hundred pod weight than the overall mean of each growing season.

Hand and mechanical harvesting was initiated at the immature green pod stage, when pods were still green and the seeds filled 80-85% of the pod cavity. A significant difference for green pod yield was observed between the manual and mechanical methods of harvesting. The cultivars harvested by hand had green pod yield overall mean of 11592 kg ha^{-1}, while the mechanical harvested cultivars had 6070 kg ha^{-1}. There was a significant cultivar x method interaction. This interaction result suggested that method of harvest was not consistent in harvesting one cultivar from another. Comparing the two methods of harvest, the yield reductions of the cultivars when harvested mechanically were 61, 62, 43, and 26 % for cultivars Kahala, Kanrich, Asmara, and Owens, respectively (Figure 1). In manual harvesting all small pods with a single bean were included in the weight, while in mechanical harvest the small and light pods were blown away along with the leaves and broken stems at the time of harvesting. The two cultivars that seemed to best fit to mechanical harvesting were Owens and Asmara with mean plant heights of 55 and 66 cm, respectively, and Kahala and Kanrich had mean plant heights of 81 and 98 cm, respectively. In this study, a plant height in the range of 55 to 66 cm appeared to be ideal for mechanical harvesting. Cultivars with higher plant height means than Owens and Asmara tended to lose more pods during mechanical harvesting and tended to intertwine with the picker shaft and leave more pods on the plants.

Virginia farmers face severe challenges in today's competitive agriculture situation. Demand for tobacco, that has provided a steady income from farm families throughout mid-Atlantic and Southern states, has fallen off due to successful efforts to reduce smoking. The federal tobacco quota system has been eliminated in recent years through a government buyout. The net result has been a reduction in the amount of tobacco grown and the number of farms growing tobacco. Farmers must now compete on a world market price. This has caused many small farms to no longer produce tobacco. The economic problem is more pronounced among farmers relaying primarily on tobacco as a cash crop. Throughout the Mid-Atlantic and Southern states, tobacco acreage has been on a downward trend for decades, and production has plummeted over the past eight years because of several factors including declining U.S. smoking rates, increased competitive pressure on large cigarette makers and, most significantly, an exodus of buyers to foreign markets such as Brazil and Africa for cheaper tobacco leaf. "In 1997, Virginia farmers made about $191 million in cash receipts from 53,000 acres of tobacco. By year 2004, tobacco production had dropped to about 30,000 acres" (Blackwell, 2005).

Utilization of mechanical harvesting and identification of cultivars adapted to mechanical harvesting will help Virginia farmers adopt vegetable soybean as an alternative crop production. Farmers already growing soybeans will notice the agronomic practices of vegetable soybeans are similar to grain-type production systems. Therefore, farmers will quickly realize economic benefits from growing vegetable soybean. Soybeans are popular among farmers who practice crop rotation due to their capability to improve soil quality. Vegetable soybeans have a higher profit

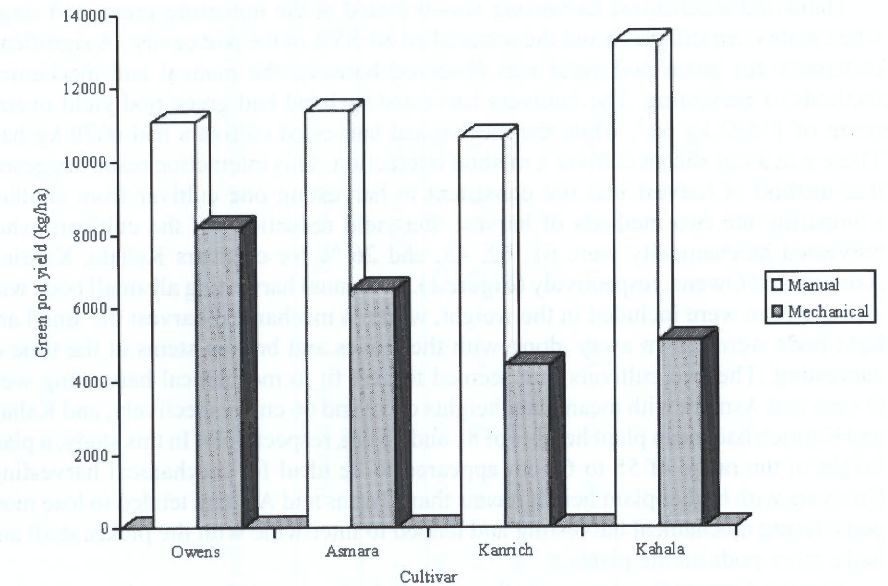

Figure 1. Frequency distribution of green pod yield of vegetable soybean cultivars harvested manually and mechanically.

margin than grain-type soybeans. Karlen et al. (2004) reported that food grade soybean grown organically returned $1150 to $1250 ha^{-1} compared to $235 for conventional soybean growing in 2 years rotation with corn (*Zea mays* L.).

Although, the United States produces more soybeans than all other soybean producing countries combined it can not meet the growing internal demand of vegetable soybean. At least 70% of the green soybean consumed in the U.S. are imported to meet the market for Asian specialty food products and the increasing number of health conscious individuals. There are around 261,000 Asians in Virginia (U.S. Census Bureau, 2003) alone and they are looking for this specialty soybean. Vegetable soybean is currently gaining popularity with organic growers who target niche commodities for specialty markets and upscale restaurants. Therefore, there is an upward trend for quality soybean cultivars in this niche market. Virginia farmers will require superior cultivars with high nutritional quality to meet this challenge in the near future.

CONCLUSION

Significant difference was observed for green pod yield among hand and mechanical methods. Comparing hand and mechanical harvest, the yield

reductions of the cultivars when harvested mechanically were 61, 62, 43, and 26 % for cultivars Kahala, Kanrich, Asmara, and Owens, respectively. However, the pods harvested mechanically were cleaner and required no further cleaning as compared to hand harvested pods. The two cultivars that seemed to best fit to mechanical harvesting were Owens and Asmara with mean plant heights of 55 and 66 cm, respectively, and Kahala and Kanrich had mean plant heights of 81 and 98 cm, respectively. This study suggested a plant height in the range of 55 to 66 cm appeared to be suitable for mechanical harvesting. This study further provides valuable information to soybean breeders and producers. First, soybean breeders could include in their breeding programs the development of cultivars with architectural traits that are suitable to mechanical harvest, and second the producers will be able to select before planting cultivars with appropriate plant height for mechanical harvest. Educating the consumers with preparation, cooking, and consumption methods, and developing better flavor and quality varieties are very important for a dramatic increase in demand. This demand, along with the ability to plant cultivars that harvest well mechanically will accelerate vegetable soybean production in Southeast of U.S.

ACKNOWLEDGMENT

The authors would like to thank to the Specialty Crops Office of Virginia Department of Agriculture and Consumers Services for their financial support to under take this study. The authors are thankful to Mr. Luis Coral for assistance with field work.

LITERATURE CITED

Blackwell, J. R. 2005. Leaf no longer top cash crop for Virginia farmers Richmond. Times- Dispatch, Nov. 24, 2005 Issue Page A1 and A11.

Carroll, K. K. and E. M. Kurowska. 1995. Soy consumption and cholesterol reduction: Review of animal and human studies. Journal of Nutrition 125:594S-507S.

Fehr, W. R. C. E. Caviness, D. T. Burmood, and J.S. Pennington. 1971. Stage of development description of soybean (*Glycine max* (L.) Merrill). Crop Science 11:929-930.

Food and Drug Administration (FDA). 1999. Food Labeling: health Claims: Soy Protein and Coronary Heart Disease. Federal Registrar 57:699-733.

Frank, S. and W. R. Fehr. 1981. Associations among pod dimensions and seed weight in soybeans. Crop Science 21:547-550.

Liu, K. S. 1999. Nonfermented oriental soybeans chemistry. Pages 137-217 *in* K. S. Liu, ed. Soybeans: Chemistry, Technology, and Utilization. New York: Chapman & Hall.

Karlen, D., K Delately, R. Turnbull, and J. Boes. 2004. Organic soybean production: Challenge and perspective of an increasing trend. Pages 319-327 *in* F. Moscardi, C.B. Hoffmann-Campo, O. F. Saraiva, P. R. Galerani, F. C. Krzyzanowski, and M. C. Carrao-Panizzi, eds. Proceeding VII World Soybean Research Conference. Faz do Iguassu, PR, Brazil-February 29 through March 5, 2004.

Kritchevsky, D. 1994. Dietary protein and cholesterol homeostasis: An historical perspective. Proceedings of First International Symposium in the Role of Soy in Preventing and Treating Chronic Disease. Mesa, AZ P-7.

Mebrahtu, T., T. Devine, P. Donald, and T. S. Abney. 2005a. Registration of 'Asmara' vegetable soybean. Crop Science 45:408-409.

Mebrahtu, T., T. Devine, P. Donald, and T. S. Abney. 2005b. Registration of 'Randolph' vegetable soybean. Crop Science 45:2644-2645.

Potter, S. M. 1994. Soy protein lowers cardiovascular disease risk. The Soy Connection. 1:1-4.

Roberts, L. 1987. Study bolsters case against cholesterol. Science 237:28-29

SAS. 2001. SAS System Ver 8 for Windows. SAS Institute, Inc., Cary, NC.

Shanmugasundaram, S., S-T. Chang, M-T. Huang, and M-R. Yan. 1991. Varietal improvement of vegetable soybean in Taiwan. Pages 30-42 *in* S. Shanmugasundaram, ed. Vegetable soybean: research needs for production and quality improvement Asian Vegetable Research and Development Center, Taiwan.

Shanmugasundaram, S., S.C.S. Tsou, and T. L. Hong. 1997. Vegetable soybeans production and research. Pages 529-532 *in* V B. Napompeth, ed. Proceeding of the 5th World Soybean Research Conference. 21-27 Feb. 1994, Kasetsart University Press, Bangkok, Thailand.

Silbernagel, M J., W. Janssen, J. H. C. Davis, and M. Monete de Octa.1991. Snap bean production in the tropics: implications for genetic improvement. Pages 835-862 *in* A. Van Schoonhoven and O.Voyset, eds. Common Beans Research for Crop Improvement. CAB International, Oxon, UK.

Steel, R. G. and J. H. Torrie. 1980. Principles and Procedures of Statistics. McGraw – Hill, New York.

United States Census Bureau. 2003. [Online]. Available at http://www.infoplease.com/us/census/data/virginia/(accessed 20 June, 2007). United States Census Data Virginia.