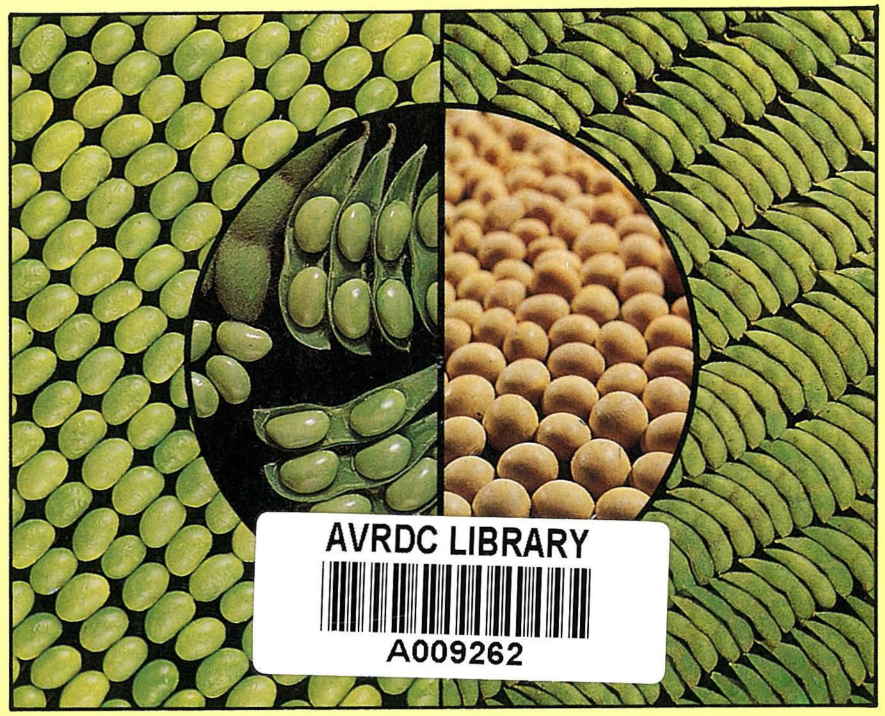
Vegetable Soybean

Research Needs for Production and Quality Improvement



Council of Agriculture, Republic of China
Provincial Department of Agriculture and Forestry, Taiwan
Asian Vegetable Research and Development Center

Vegetable Soybean
AVRDC

Vegetable Soybean

Research Needs for Production and Quality Improvement

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Research Needs for Production and Quality Improvement

Proceedings of a workshop held at Kenting, Taiwan
29 April-2 May 1991

S. Shanmugasundaram, *Editor*

Organized by

Council of Agriculture, Republic of China
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Contents

Welcome Address

Yong-Sin Chang
Council of Agriculture, Taipei

Dr. Te-Yeh Ku, Director of the Agriculture Department of the Council of Agriculture, asked me to represent him at this important workshop. On behalf of the Council of Agriculture and Dr. Ku, I am honored to welcome all of you to the workshop and to Taiwan.

The vegetable soybean industry in Taiwan was an insignificant one in the 1970s. But today there are about 30 frozen food processing factories handling a sizeable volume of vegetable soybean for export—primarily to Japan. The total value of vegetable soybean export to Japan and other countries in 1990 reached an all-time high of about US$75 million. Vegetable soybean constitutes nearly 60% of the total export of all fruits and vegetables processed in Taiwan. Therefore, we are very much interested in this commodity.

In the early 1980s, the Council of Agriculture recognized the growing importance of vegetable soybean for export and for the domestic market in Taiwan. In 1985, the Council initiated and supported a vegetable soybean research project at the Kaohsiung District Agricultural Improvement Station and the Asian Vegetable Research and Development Center.

Kaohsiung DAIS and AVRDC responded to the research challenge of developing an improved variety within a very short period of time. In 1987, AVRDC's selection AGS 292 was released by Kaohsiung DAIS as Kaohsiung No. 1, which I understand occupies about 84% of the total area cultivated in vegetable soybean in Taiwan. I congratulate all the scientists at Kaohsiung DAIS and AVRDC responsible for the successful development and extension of Kaohsiung No. 1 to our farmers.

Several constraints may limit the future of the vegetable soybean industry in Taiwan. I hope your expert deliberations in this workshop will solve those problems.

The Council is very pleased to cosponsor this workshop and to support the research activities. We are confident the workshop will be mutually beneficial to Japan and Taiwan, and the outcome will be valuable to other countries.

The Council will continue to provide strong support to AVRDC, Kaohsiung DAIS and other concerned organizations in Taiwan, to undertake research to achieve the recommendations of the workshop. We want the vegetable soybean farmers and the processing industry as well as the consumers to benefit from your research.

I look forward to your successful deliberations and on behalf of the Council of Agriculture I wish to express my thanks to those who have put in so much effort to make this workshop a reality.

Welcome Remarks

Shue-Cheng Lin
Provincial Department of Agriculture and Forestry, Taiwan

On behalf of Dr. Paul Sun, Commissioner of Provincial Department of Agriculture and Forestry in Taiwan, I welcome you to this important workshop.

It gives me great pleasure to see that the Council of Agriculture in Taiwan initiated and cosponsored this workshop with AVRDC and PDAF. This is the first workshop of its kind on vegetable soybean. On behalf of our Commissioner and PDAF, we extend our warmest welcome to all the delegates from Japan, USA, Thailand, Denmark, AVRDC and my colleagues from Taiwan.

Vegetable soybean is a very important crop for our farmers in the southern part of Taiwan, especially the Kaohsiung-Pingtung area and Tainan. The prosperity and the standard of living enjoyed by our country have progressively raised the cost of production of vegetable soybean in recent years. Thanks to the efforts of the Kaohsiung District Agricultural Station and AVRDC, the release of Kaohsiung No. 1, a new improved vegetable soybean variety, in 1987 saved our vegetable industry. Kaohsiung No. 1 is high yielding, acceptable to the Japanese market and profitable to farmers and the industry. PDAF is proud to have played a role in the timely seed multiplication and distribution of this improved variety to the farmers. We take this opportunity to congratulate Kaohsiung DAIS and AVRDC, and we look forward to their further research advances to help our vegetable soybean farmers.

To reduce the cost of production we are now experimenting, through AVRDC and Kaohsiung DAIS, with mechanical harvesting. We hope that varietal development and management as well as quality evaluation will address the mechanization aspect to benefit farmers and sustain vegetable soybean in Taiwan. We look forward to the suggestions and recommendations of the international delegates so that research output can be beneficial to everyone around the world.

PDAF will continue to provide strong support for vegetable soybean research and extension in Taiwan as long as it addresses farming and industrial needs.

Once again, welcome to this workshop, and I wish you a successful meeting. While you are here please enjoy our beautiful Taiwan.

Opening Remarks

Emil Q. Javier
Asian Vegetable Research and Development Center

It is my pleasure to welcome all of you to this workshop. Vegetable soybean is a popular food in China, Japan and Korea where it is enjoyed for its fine taste and high nutritional value as a source of vitamins, minerals, protein, energy and fiber. However, it has great potential to developing countries, where it is as yet relatively unknown, not only for the above virtues but also because of its high income value for small farmers, its versatility as a crop to fit into cropping systems, its potential as source of fodder for livestock and soil-enhancing properties.

This workshop is significant because as far as we know this is the first international meeting that focuses exclusively on the research needs for this nutritious and versatile crop. Thus we have brought together the leading experts on the crop both in Japan and Taiwan where the crop is most popular, to assess the status of the crop, the present problems, the priorities for research and possibilities for future collaboration.

Allow me, therefore, to briefly thank all of you, particularly the speakers, for taking the time to prepare papers and participate in this workshop.

Our special thanks and recognition go to the Council of Agriculture of the ROC and the Taiwan Provincial Department of Agriculture and Forestry for their sponsorship of this workshop and for their continuing and strong support to AVRDC. Both Dr. T.Y. Ku and Dr. Paul Sun were unable to attend, but they sent their representatives, Dr. Chang and Dr. Lin, to convey their assurance of interest and support.

We want to recognize particularly our partners from the Kaohsiung and Tainan DAIS represented by Dr. Y.S. Cheng and Dr. S.C. Lin with whom our scientists work very closely on soybean improvement. We consider ourselves very fortunate to have them as partners and congratulate them for their contributions to the development of the local vegetable soybean industry.

Vegetable Soybean Area, Production, Demand, Supply, Domestic and Foreign Trade in Japan

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Abstract

During the last decade vegetable soybean production decreased slightly in Japan whereas vegetable soybean imported from foreign countries increased. Domestic consumption of both domestically produced vegetable soybean and imported ones has not increased in the last 5 years in Japan. In order to expand the market of vegetable soybean and enhance the profit of soybean farmers, it is necessary: (1) to expand the market and production in the southern and western areas of Japan; (2) to develop techniques for low-cost forcing culture during winter to early summer; (3) to improve the methods of transportation from remote warm regions to large consumption centers such as Tokyo and Osaka; (4) to improve the quality and increase the number of vegetable soybean varieties; and (5) to create new dishes based on vegetable soybean, in addition to the usual boiling method.

Demand and Production

Vegetable soybean is not included among the most important 14 vegetables whose supply and price are specifically controlled by the Japanese government. It is included among 29 other vegetables whose lowest price is controlled by the government. The area under cultivation of vegetable soybean is only 14,400 ha (ranking 18th for all vegetables) and the production of vegetable soybean amounts to 104,500 t (ranking 24th for all vegetables) in Japan. In spite of the increase in area and production recorded until about 1980, the area under cultivation thereafter did not increase and the production even slightly decreased during the last decade (Fig. 1).

The amount of vegetable soybean shipped to wholesale markets also gradually decreased in the last 5 years, whereas that imported from foreign countries increased. During this period domestic consumption of both domestically produced vegetable soybean and imported ones did not increase (Fig. 2).

The situation of vegetable soybean reflects the production and the consumption of vegetables in general. Although rice and vegetables had been the main components of Japanese food, since 1975 rice consumption has gradually decreased with the westernization of the eating habits of the Japanese people. The consumption of vegetables has remained steady. The same may apply to the consumption of vegetable soybean.

In 1988, the supply of vegetables per caput per year was about 110 kg in Japan, with vegetable soybean accounting for only 0.29 kg. The supply of vegetable soybean was less than that of vegetable kidney beans and garden peas, accounting for 0.66 kg, though it was more than vegetable faba beans, with very short harvesting period, at 0.06 kg. Vegetable soybeans are consumed only as a snack with alcoholic beverages, especially beer, in Japan. In order to expand the consumption of vegetable soybean, it is therefore necessary to develop new uses.

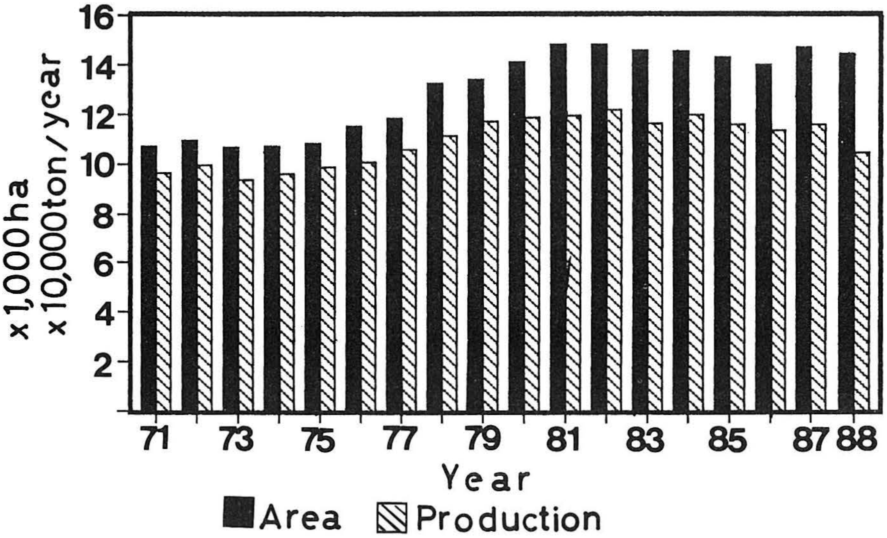

Fig. 1. Changes in vegetable soybean cultivation area and annual production in Japan.

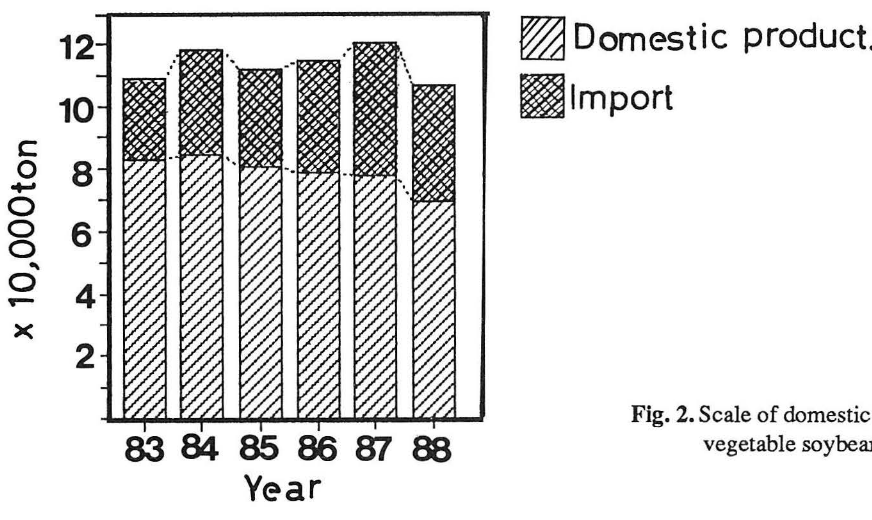

Fig. 2. Scale of domestic consumption of vegetable soybean in Japan.

Regional Differences in Production and Consumption

Vegetable soybean culture is extensively practiced in the Tohoku district and the Kanto district in the northern part of Japan, and to a lesser extent in the western part (Fig. 3). In the Kyushu district, none of the prefectures produce more than 400 t of vegetable soybean per year. The consumption of vegetable soybean per caput can be estimated from the amount shipped to a wholesale market in each city. The consumption is low in the Chugoku and Kyushu districts in contrast to the Tohoku and Kanto districts (Fig. 4).

The low production of vegetable soybean in the Kyushu district is due to the low preference for vegetable soybean on the part of the consumers, in addition to frequent insect damage in soybean culture, high transportation costs and difficulty in keeping the produce fresh during transportation because the prefectures in the Kyushu district are far from large consumption centers such as Osaka, Nagoya and Tokyo.

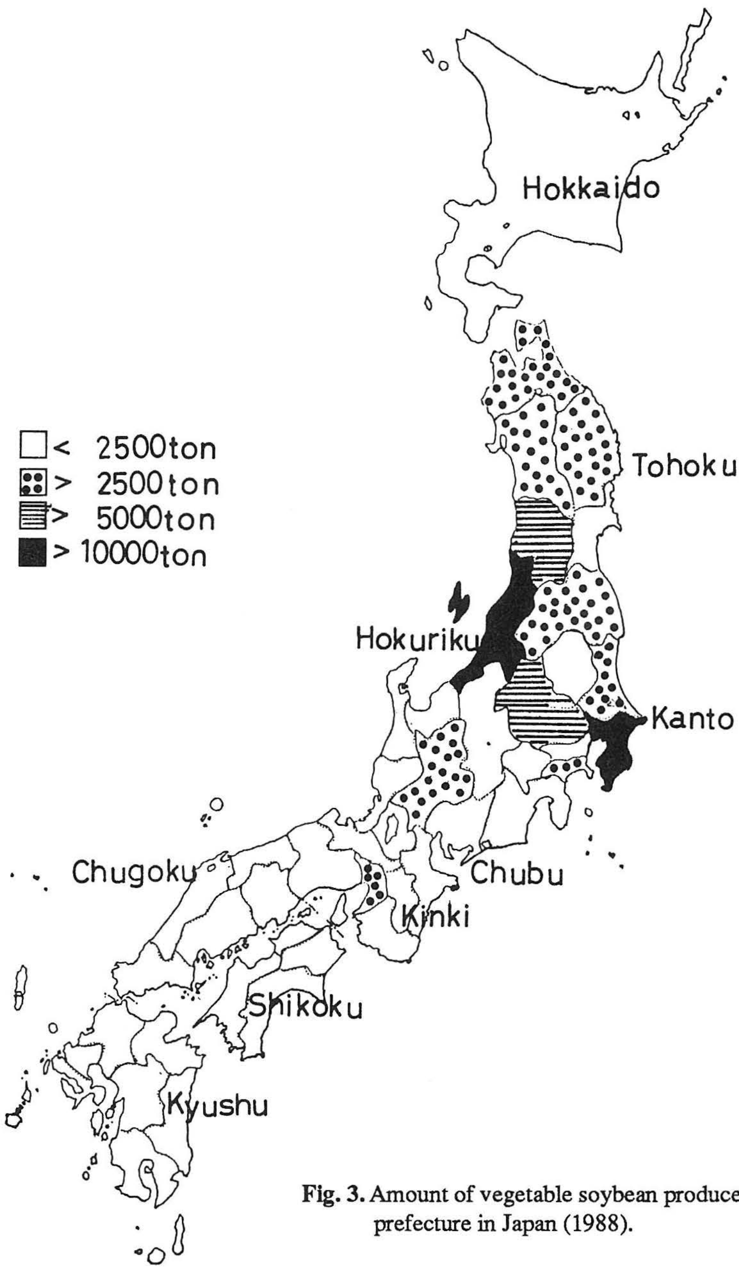

Fig. 3. Amount of vegetable soybean produced by each prefecture in Japan (1988).

Seasonal Changes in Production and Demand

Vegetable soybean is mainly available from July to September at Tokyo wholesale market (Fig. 5). Demand for vegetable soybean is high in the summer season. However, as mentioned above, vegetable soybean is consumed only as a snack with alcoholic beverages, especially beer. The consumption of beer is not so high in the summer season compared to the consumption of vegetable soybean. Recent surveys showed that beer consumption is distributed more evenly throughout the year (Fig. 5).

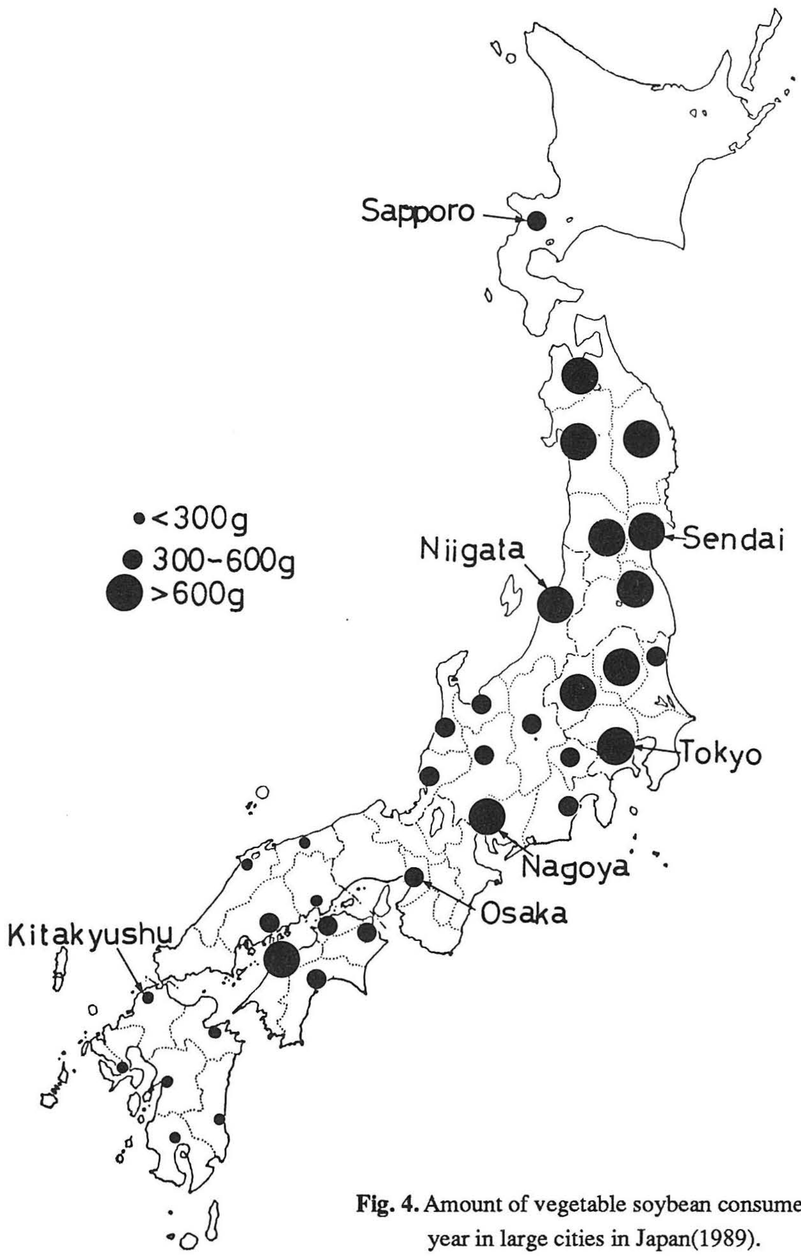

Fig. 4. Amount of vegetable soybean consumed per caput per year in large cities in Japan(1989).

Vegetable soybeans domestically produced are distributed as fresh vegetable soybeans. In seasons other than summer, frozen vegetable soybean is consumed, but the taste is not appreciated as much as the fresh ones by Japanese consumers. If fresh vegetable soybean could be supplied throughout the year, the consumption of vegetable soybean may increase. For example, at the Kitakyushu wholesale market the supply of vegetable soybean is already high in June, because a large amount is shipped from Kagoshima prefecture in the southern part of the Kyushu district. Thus if techniques for the transportation from remote warm regions (including foreign countries) to large consumption centers such as Tokyo could be developed, and if low-cost forcing culture could be improved, the consumption of fresh vegetable soybean during winter to early summer may increase in Japan.

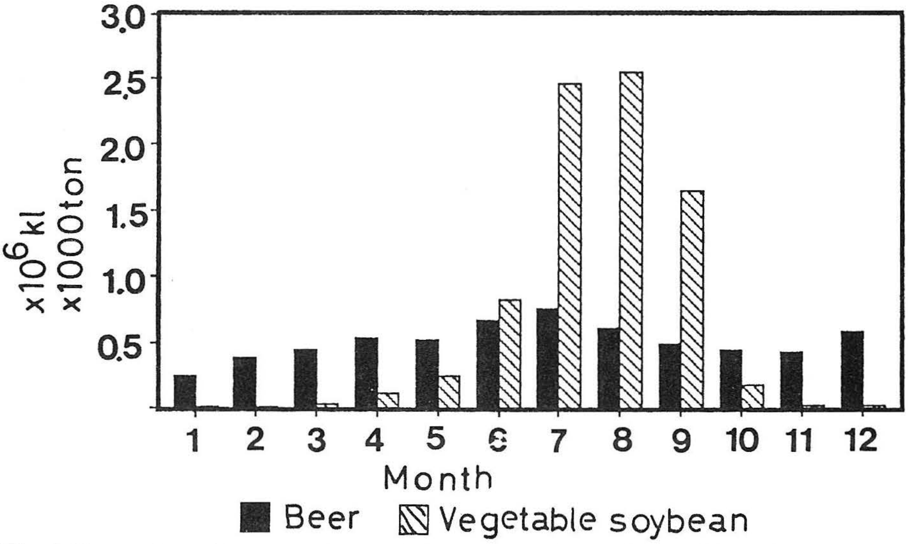

Fig. 5. Comparison of seasonal changes in beer consumption and vegetable soybean consumption (1989). Beer: amount produced in Japan, Vegetable soybean: amount supplied at Tokyo wholesale market.

Price of Vegetable Soybean

The price of vegetable soybean is high except in summer in Japan. When the monthly supply exceeds 500 t at Tokyo wholesale market, the upper price limit is only about 600 yen/kg (Fig. 6) (US$ 1 = ¥140; mid 1991). When the monthly supply is less than 500 t, the price increases markedly, in particular from November to May of the following year in Tokyo (Fig. 7).

The contribution of various districts to the supply of vegetable soybean at the Tokyo wholesale market each month is shown in Fig. 8. From the winter months to April, vegetable soybean grown in heated greenhouses is supplied from areas south and west of Tokyo, especially Shizuoka prefecture

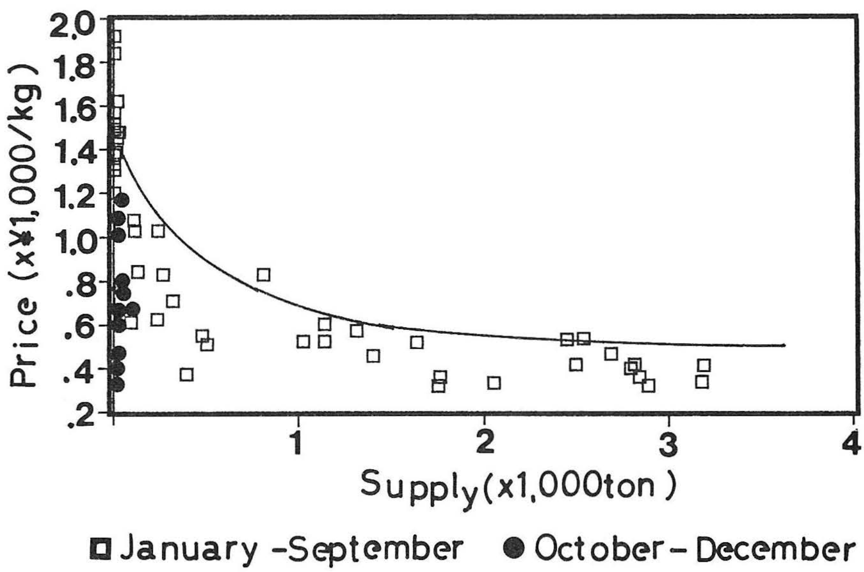

Fig. 6. Relation between price and amount of vegetable soybean supplied in a month in the Tokyo wholesale market (1985-89).

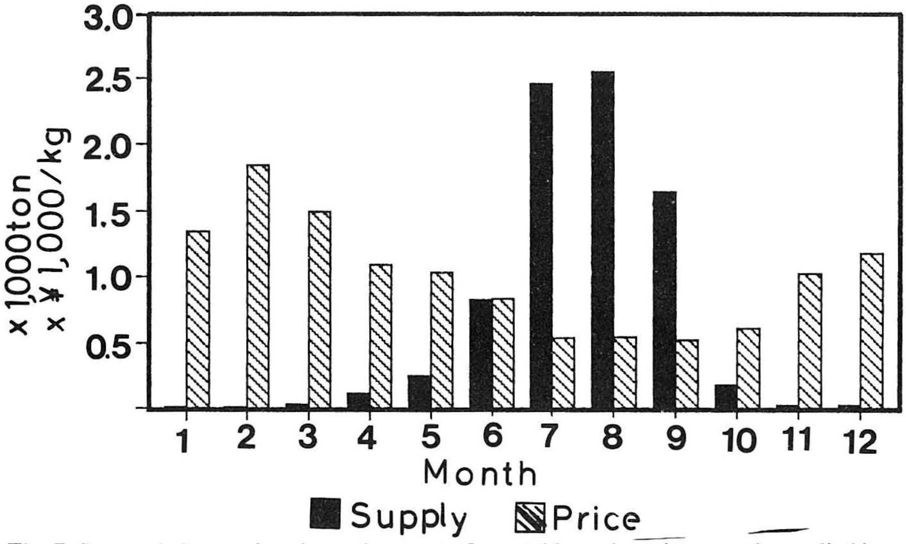

Fig. 7. Seasonal changes in price and amount of vegetable soybean in a month supplied in the Tokyo wholesale market (1989).

(Fig. 8,9). Imported fresh vegetable soybean is supplied from March to May. In May and June, soybean grown by forcing culture in plastic tunnels and in nonheated greenhouses originates from various regions near Tokyo. During the summer which corresponds to the period of high supply, considerable quantities of vegetable soybean grown outdoors in the Kanto district near Tokyo reach the market at the low price of 500 yen/kg (Fig. 7). After the summer peak, vegetable soybean grown outdoors mainly in the Tohoku district is supplied late, in September and October. Although the amount of vegetable soybean supplied is low in October, the price is also low due to the low demand in these months, following the summer with high supply, during which consumers become satiated.

At the Tokyo wholesale market, vegetable soybeans shipped from Shizuoka prefecture fetch a higher price in all seasons, because Shizuoka prefecture accounts for the largest quantity of vegetable soybeans produced through forcing culture in greenhouses in winter and spring. In addition, vegetable soybeans from this prefecture fetch high prices also in summer due to their high quality (Fig. 10).

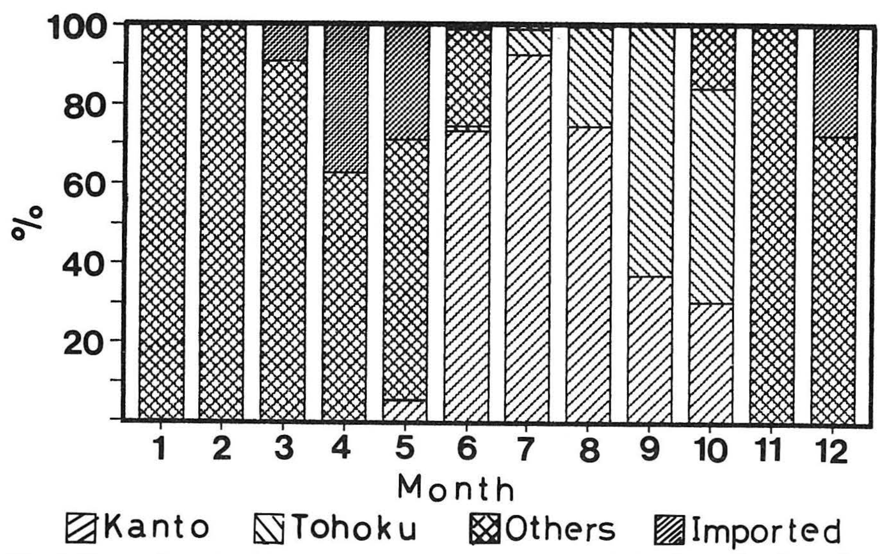

Fig. 8. Share of supply of fresh vegetable soybean to Tokyo wholesale market, by various districts (1990).

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                                        Month
                         ------------------------------------------------
                          1  2  3  4  5  6  7  8  9  10  11  12
---------------------------------------------------------------------------
  Green house             ●●-*********                             ●●●●●●
   (heated)
---------------------------------------------------------------------------
  Green house                ●●●●-----******
 (non-heated)
 Plastic tunnel              ●●●●●●●----*****
---------------------------------------------------------------------------
   Outdoors                        ●●●●-----*****
---------------------------------------------------------------------------
   Outdoors                              ●●●●----*******
(Northern region)
---------------------------------------------------------------------------
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Fig. 9. Vegetable soybean production calendar in Japan. •••• sowing period, *** harvesting period (adapted from Khono 1989).

There are two types of packing methods for shipping vegetable soybeans. For the attached type, roots, leaves except top leaf, and small or damaged pods are removed and the whole plant with pods on stem and branches are shipped. For the detached type, small or damaged pods are removed, and selected good pods are packed in a plastic net bag for shipping. Usually farmers earn more money with the attached type than the detached type. However, in the attached type the cost of transportation increases due to the large volume of the branches. As a result, farmers close to large cities mainly ship the attached type consisting of early-maturing soybean varieties, with a short plant height. Since the Japanese

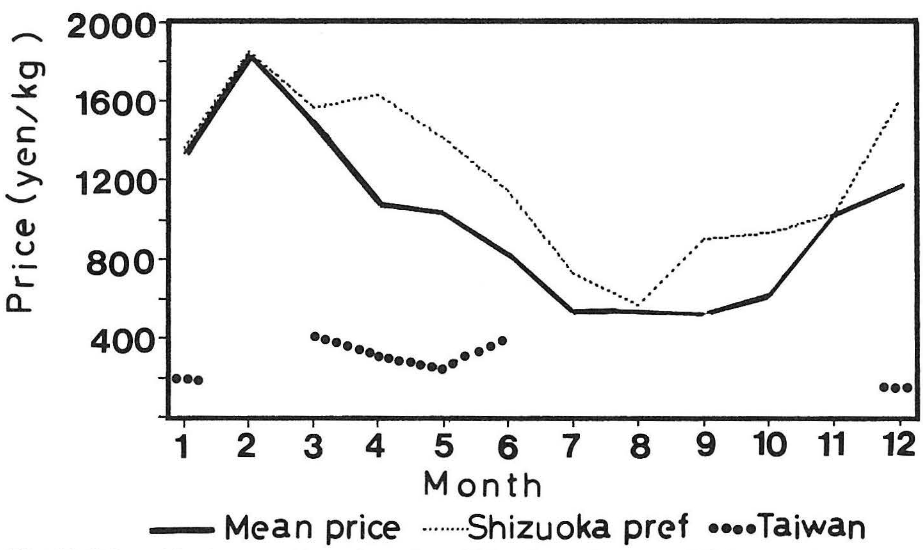

Fig. 10. Price of fresh vegetable soybean from Shizuoka prefecture and Taiwan at the wholesale market (1989). Mean price indicates the mean of all vegetable soybeans dealt at the Tokyo wholesale market.

consumers prefer vegetable soybeans with freshness and good appearance, they are willing to pay a premium price for the attached type. On the other hand, there is also a demand for the detached type by some consumers who dislike detaching pods from branches and discarding the branches.

Distribution of Imported Vegetable Soybeans

The imports of frozen vegetable soybean amounted to 34,000 t in 1989 (Fig.2), with Taiwan accounting for 99% of the total. The People's Republic of China and USA account for a very small amount. Frozen vegetable soybean is imported by trading companies and distributed directly, through a commission agent or through a wholesale market, to supermarkets, restaurants and retail shops. Fresh vegetable soybeans are also imported from Taiwan during March-May. The People's Republic of China, Thailand and Mexico also export a very small amount of detached type, the annual total of which ranged from 2000 to 3000 t during 1987-90. Most of the fresh vegetable soybean is distributed through wholesale markets. Ratio of imported fresh vegetable soybean to the total amount of vegetable soybean dealt was only 1.6% in the fresh vegetable division of the Tokyo wholesale market and 0.7% in Sendai in 1990, with 6.5% in Kitakyushu and 17.5% in Osaka in the western part of Japan. The price of imported soybean is also higher in Osaka (305 yen/kg at Osaka wholesale market) than in Tokyo (169 yen/kg at Tokyo wholesale market in 1988). The price of imported fresh vegetable soybean is low due to the low quality caused possibly by preparation for shipping and transportation. They are used when the supply of domestically produced vegetable soybean is scarce (Fig. 10).

Cost and Earnings in the Production of Vegetable Soybean

Japanese farmers choose to grow vegetable soybean over other vegetables for a variety of reasons, including profit. For example, an investigation of standard farmers shows that the total cost of growing and shipping amounts to 1,240,000 yen/ha for open culture, 1,950,000 yen/ha for forcing culture with plastic tunnels, and 4,500,000 yen/ha for forcing culture in heated plastic greenhouses (Fig. 11). These values are low in comparison with those of other vegetables. However, the net income derived from vegetable soybean culture is also not higher than that from other vegetables (Fig. 12). Vegetable soybean culture is practiced by farmers for the following reasons: (l) culture is easy compared with fruit vegetable culture; (2) elderly farmers and women can easily handle the lightweight soybean plants; (3) the harvest and preparation of pods for shipping, which is relatively easy even for elderly farmers and women, who account for 60-80% of all the operations in vegetable soybean culture. In some areas, however, farmers also try to produce special vegetable soybeans that fetch a high price. For example, vegetable soybeans from Yamagata prefecture fetch a high price even in August, the peak consumption time in Tokyo, since Dadachamame, a local variety from Yamagata, is noted for its unique taste. Kurosakichamame, a brown seeded variety in Niigata prefecture and Tanbaguro, a black and large seeded variety in Kyoto prefecture, are also promoted as local special products to expand the market by the agricultural cooperative associations.

Conclusions

In conclusion, to expand the market for vegetable soybean and enhance the profit of farmers in Japan, it is recommended: (1) to expand the market and production in the southern and western areas of Japan, for example the Chugoku and Kyushu districts; (2) to develop techniques for low-cost forcing culture so as to produce vegetable soybean of good quality during winter to spring; (3) to improve the methods of preparation for shipment and transportation of fresh vegetable soybean; (4) to improve the quality and increase the number of vegetable soybean varieties with good taste.

For imported fresh vegetable soybean, it is important to develop low-cost transportation techniques. Furthermore, it is necessary to create new dishes using vegetable soybeans, in addition to the usual boiling method.

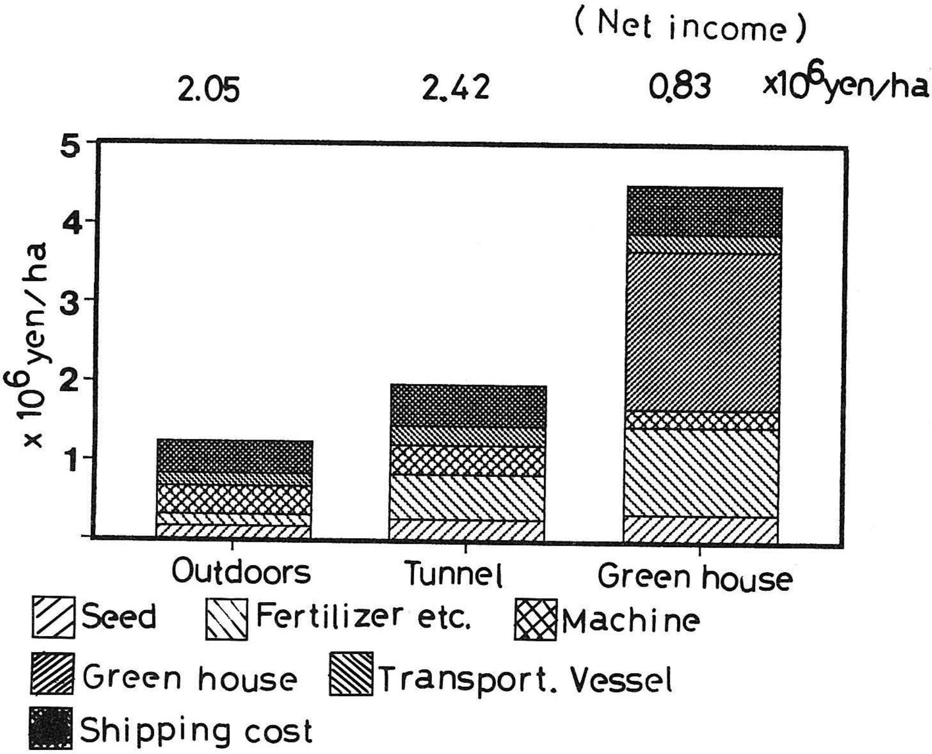

Fig. 11. Production cost of vegetable soybean. Transport: price of package vessels; Shipping cost: cost of transportation and shipping charges.

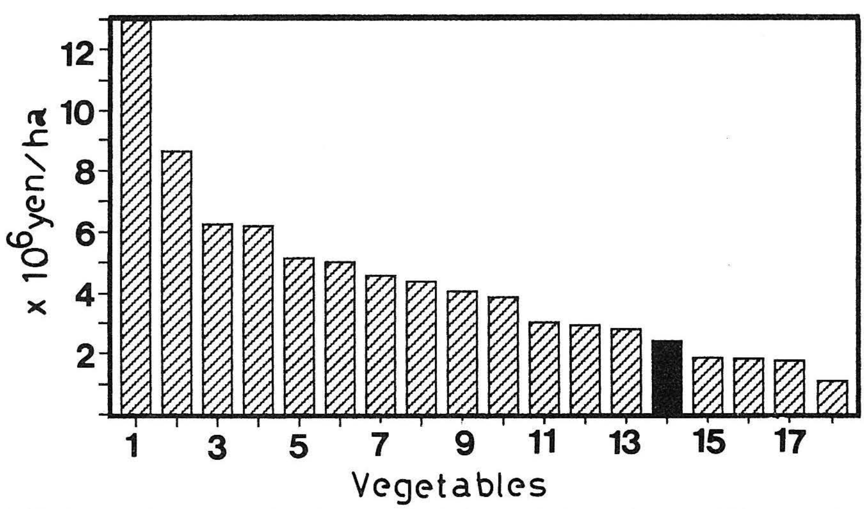

Fig. 12. Net income from vegetable culture in plastic tunnels in Japan. 1: vegetable pepper; 2: eggplant; 3: melon; 4: kidney bean; 5: bell pepper; 6: gynmigit; 7:oriental pickling melon; 8: cucumber; 9: tomato; 10: pumpkin; 11: watermelon; 12: melon (cv. Prince); 13: head lettuce; 14: vegetable soybean; 15: carrot; 16: vegetable maize; 17: Chinese cabbage; 18: Japanese radish.

References

Khono, M. 1989. Vegetable soybean. In: Nobunkyo (ed.) Encyclopedia of Vegetables and Horticulture. Tokyo: Nouson Gyoson Bunka Kyoukai, 413-429. (Translated from Japanese by Nakano.)

Vegetable Soybean Area, Production, Foreign and Domestic Trade in Taiwan

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Abstract

Vegetable soybean harvested when the pod is still green and full is rich in protein, fat, minerals and vitamins. Vegetable soybean is grown in the Kao-Pin area during the fall and Kao-Pin and Chia-Nan areas in the spring in Taiwan. The area and total production varied from 7139 ha and 42,389 t in 1983 to 9852 ha and 63,163 t in 1990. There was a larger area and higher production in the fall crop than in the spring crop. The average yield reached 6.0 t/ha in 1987. The export volume of vegetable soybean in Taiwan increased from 452 t in 1972 to 34,821 t in 1989. About 80% of total production was for export. The export value (FOB) increased from US$47.6 million in 1987 to US$75 million in 1990. The major market for the export of frozen vegetable soybean is Japan, which bought 99% of the total export volume in 1989. The cultural practices for vegetable soybean are similar to those for grain soybean. A new leading cultivar, KS # 1, bred by AVRDC and Kaohsiung District Agricultural Improvement Station (DAIS), was the first official release of vegetable soybean in Taiwan. High production cost and shortage of harvest labor are constraints to vegetable soybean production and export. It is most urgent, therefore, to build up a mechanized cultural system. More attention should be directed to varietal improvement, integral production technology, and seed production systems.

Introduction

Soybean (*Glycine max*) has been traditionally the favorite legume in the Chinese diet. Vegetable-type soybean, rich in protein, fat (with no cholesterol), minerals, and vitamins, is harvested between R_6 and R_7 growth stages, when the pod is still green and full. Prior to 1971 vegetable soybeans in Taiwan were normally shelled and marketed as fresh beans. More recently vegetable soybean frozen in the pod and exported to Japan has become the number one export crop product in Taiwan.

Vegetable soybean is primarily grown in the Kaohsiung-Pingtung area in southern Taiwan during the fall season, and rotated as a cash crop between second and first crops of paddy rice. In recent years the spring season crop has been gaining in importance both in Kao-Ping and Chia-Nan areas (Cheng and Shanmugasundaram 1989).

Area, Production and Yield

The area planted to vegetable soybean increased from 7139 ha in 1983 to 9852 ha in 1990 (Table 1). Two crops of vegetable soybeans a year are grown in Taiwan. The area in the spring crop season has steadily increased since 1983 while that in the fall crop season remained unchanged.

The total production varied from 42,389 t in 1983 to 63,163 t in 1990, because of increases of both area planted and yield (Table 2). Production was higher in the fall crop than in the spring crop. The average yield has exceeded 6.0 t/ha since 1987, mostly as a result of the new cultivar Kaohsiung Selection No. 1 released by the Kaohsiung DAIS. The average unit price for graded vegetable soybean pods rose from NT$17.8/kg in 1983 to NT$23.0/kg in 1990 (Table 2).

Table 1. Area planted to vegetable soybean in Taiwan, 1983-90.

Year	Area (ha)		
	Spring	Fall	Total
1983	2,206	4,933	7,139
1984	2,577	4,092	6,669
1985	2,512	4,358	6,870
1986	3,116	5,349	8,465
1987	4,379	5,070	9,449
1988	3,896	3,751	7,647
1989	3,229	4,021	7,250
1990	5,092	4,760	9,852

Source: PDAF (1991).

Table 2. Vegetable soybean production, yield and unit price in Taiwan, 1983-90.

Year	Production (t)			Yield	Price*
	Spring	Fall	Total	(kg/ha)	(NT$/kg)
1983	13,187	29,202	42,389	5,938	17.8
1984	13,308	25,220	38,528	5,777	17.0
1985	14,459	26,473	40,932	5,958	16.8
1986	19,611	29,761	49,372	5,832	18.0
1987	27,978	30,201	58,179	6,157	19.5
1988	23,017	23,554	46,571	6,091	19.1
1989	19,610	23,899	43,509	6,001	20.8
1990	32,500	30,663	63,163	6,411	23.0

Source: PDAF (1991).
*Contractual unit price is averaged over crop seasons and cultivars (US$1=NT$27.2 - April 1991).

Foreign and Domestic Trade

In 1971, 142 t of frozen soybean pods were exported to Japan (Chen and Chen 1987). The export volume rose from 452 t in 1972 (Wu and Cheng 1986) to 34,821 t in 1989 (Table 3). However, the export volume in recent years has remained almost static (Table 3).

During 1984-89, about 80% of total production was for export, with the balance for domestic use. The domestic consumption of vegetable soybean also steadily increased from 4710 t in 1984 to 15,824 t in 1987, and then dropped to 8688 t in 1989 (Table 3). It is estimated that the domestic consumption of vegetable soybean will be more than 20,000 t in 1990 (final data not yet available).

Table 3. Vegetable soybean foreign and domestic trade in Taiwan, 1984-90.

Year	Production	Export		Domestic use	
	(t)	(t)	(%)	(t)	(%)
1984	38,528	33,818	87.8	4,710	12.2
1985	40,932	31,044	75.8	9,888	24.2
1986	49,372	36,231	73.4	13,141	26.6
1987	58,179	42,355	72.8	15,824	27.2
1988	46,571	36,321	78.0	10,250	22.0
1989	43,509	34,821	80.0	8,688	20.0
1990	63,163	37,055*	-	-	-

Source: Anon. (1991) and Shanmugasundaram et al. (1990).
* Export volume up to October 1990.

The total export of frozen vegetables in Taiwan in 1980 was 66,569 t. Of that amount 22,355 t were frozen vegetable soybeans (Liu 1981). In 1989, the export of frozen vegetable soybean ranked tenth in export of all agriculture produce and products, but number one among export crops. The export value increased from US$47.61 million in 1987 to US$50.1 million in 1989 (FOB) and is expected to reach more than US$75 million in 1990. The unit price per kilogram also varied from US$1.12 in 1987 to US$1.70 in 1989, and rose to US$2.03 in October 1990 (Table 4). Frozen vegetable soybean in Taiwan is exported to Japan (including Okinawa), Hong Kong, Singapore, Holland, Canada, USA, Australia, etc., but the major market is Japan, which purchased about 99% of total export volume in 1989 (Anon. 1991). The frozen products of vegetable soybean pods and shelled beans are usually for export, and the fresh shelled beans are used entirely for domestic consumption. The grading criteria for exported frozen vegetable soybean to Japan are pods that have two or more seeds, bright green pods after blanching or cooking, large seed, gray pubescence, colorless hilum, more than 4.5 cm pod length and 1.3 cm pod width, and no more than 175 pods/500 g (Shanmugasundaram et al. 1990).

Table 4. Vegetable soybean export value and unit price in Taiwan since 1987.

Year	Export value (million US$/FOB)	Unit price (US$/kg FOB)
1987	47.61	1.12
1988	47.62	1.31
1989	59.10	1.70
1990	75.29*	2.04

Source: Anon. (1991).
* Based on data up to October 1990.

Cultural Practices

The cultural practices for vegetable soybean are quite similar to those for grain soybean. In general, vegetable soybean requires well-drained sandy loam or loam soil with irrigation. The planting density is 40-45 cm x 10-15 cm in the spring and summer crop season, and 30 cm x 10-15 cm in the fall. The sowing period varies with crop season: mid-February to early March for the spring crop and mid-September to early October for the fall crop. Seeding rate is about 110-120 kg/ha, in two-row beds using a planter with a ridging attachment. Fifty percent of the fertilizer is used for basal dressing during land preparation, and the other 50% as top dressing 15 days after sowing: 60 kg N/ha, 40-80 kg P/ha, and 60 kg K/ha are usually recommended (Chen and Chen 1987). In addition, diseases such as soybean rust and downy mildew and insect pests such as beanfly, pod borer, mites, etc., should be controlled, to produce a better crop.

Vegetable soybeans are harvested in the early morning to maintain their freshness. Plants are either cut or uprooted and pods are picked by hand in the field. Labor cost for harvesting is calculated by the weight of graded pods picked. Currently, it costs NT$ 6 to pick a kilogram of graded pods. For example, the average yield was about 6400 kg/ha in 1990, so the pod stripping cost would be NT$38,400/ha or US$1422/ha.

Research and Development

The Asian Vegetable Research and Development Center (AVRDC) cooperated with the Kaohsiung District Agricultural Improvement Station in organizing a vegetable soybean breeding project, which is fully supported by the Council of Agriculture, ROC. The breeding objective is to develop vegetable soybean cultivars with high yield and quality, suitable for export as frozen vegetable soybean and processing, and for mechanized cultural practices. In 1987, a new cultivar Kaohsiung Selection # 1 (KS #1) was registered. This was the first official release of vegetable soybean in Taiwan. At the end of 1990, the area covered by KS #1 accounted for 84% of the total vegetable soybean area, replacing Tzurunoko (referred to as 205) and Ryokkoh (referred to as 305) (Shanmugasundaram et al. 1990). The Kaohsiung DAIS recently applied for registration of two newly-bred promising lines as new cultivars.

Problems and Future Needs

High production cost and shortage of harvest labor are major limiting factors for the development of both production and export of vegetable soybean in Taiwan. High production cost, especially high harvest cost, will lower the competitive ability of vegetable soybean products in the domestic and Japanese market. Shortage of harvest labor will make the area devoted to vegetable soybean difficult to expand. It is therefore most urgent to develop a fully-mechanized cultural system. At the moment, a combined harvester suitable for harvesting vegetable soybean would be most helpful in lowering production costs.

As well, vegetable soybean breeding, focusing on improvement of high quality, resistance or tolerance to diseases and insect pests, processing and mechanized harvest, should be strengthened. Also, an integral production technology should be developed along with a seed production and storage system.

References

Anon. 1991. Current report on export status of frozen vegetable soybean in Taiwan. Taiwan Frozen Vegetable Processors Association, Kaohsiung.

Provincial Department of Agriculture and Forestry (PDAF). 1991. Contractual production of raw beans for exporting frozen vegetable soybean in recent years. Taiwan Provincial Department of Agriculture and Forestry. Nantou (Unpublished data).

Liu, Chung-Pi. 1981. A review of frozen vegetable soybean industry in Taiwan. Taiwan Land and Finance Quarterly, Bank of Taiwan, Vol. 18, No. 4, 141-160.

Wu, Y.L., and Cheng, S.T. 1986. Current production and marketing and prospect of vegetable soybean in Taiwan. Taiwan Agriculture. Vol. 22, No. 1, 37-41.

Shanmugasundaram, S., Tsou, S.C.S., and Cheng, S.H. 1990. Vegetable soybeans in the East. *In*: A.J. Pascale (ed.), Proceedings of World Soybean Research Conference IV, 1979-1986.

Chen, K.F., and Chen, Z.T. 1987. New vegetable soybean cultivar - Kaohsiung Selection # 1. Hsing-Nong, No. 228, 28-31.

Cheng, S.H., and Shanmugasundaram, S. 1989. Implementation and achievements in leguminous crops. Review report. Asian Vegetable Research and Development Center. AVRDC, Shanhua, Tainan (in press).

Communication Links Between Vegetable Soybean Producers, Processors, Trading Companies and Seed Companies in Japan

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Abstract

Total demand for vegetable soybean in Japan is almost 160,000 t, having remained constant for several years. Frozen vegetable soybean occupies 25–30% of the total demand. Almost 100% of the frozen vegetable soybean is imported from foreign countries, mainly from Taiwan. There is very little frozen vegetable soybean produced in Japan. Most of the vegetable soybean produced domestically is shipped for fresh marketing. Therefore, there is a close connection between producer (farmer), seed company and distributor of vegetable soybean for the fresh market. The connection is not so close between producer, processor and trading company on processing in Japan. Total demand of vegetable soybean seed is estimated at almost 800,000 l (600 t). However it is very difficult to calculate this exactly because there is considerable self-seed production by local small retail dealers or by producers themselves. They use many local native varieties for specific consumption in limited areas. As a result these self-produced seeds are not distributed through seed companies. Recently, however, consumers are demanding higher quality of vegetable soybean. Quality improvement of vegetable soybean by cultivation techniques as well as breeding is needed. Active trials to produce vegetable soybean using harvesting machines have been ongoing in Hokkaido. They aim to produce good quality frozen vegetable soybean.

Distribution of Vegetable Soybean

Total demand in 1987 for vegetable soybean was about 160,000 t. Domestic production provided about 116,000 t and about 43,000 t was imported. The frozen vegetable soybean imported met about 26% of the total demand.On the other hand, frozen domestically produced vegetable soybean occupied only 0.1% of total demand. In the last 5 years, the situation has not changed drastically.

There is a tight connection between producer, seed company and distributor, because most of the domestic production is shipped for fresh marketing in Japan. Generally, the producer (vegetable soybean farmer) buys seeds from a seed company, and then ships them to the wholesale market as fresh vegetable soybean. However, the connection between producer, processor and trading company is not so tight, because the domestic production of frozen vegetable soybean in negligible in Japan. Japanese processing companies import and sell frozen vegetable soybean through a trading company or handle it themselves. Therefore, Japanese seed companies including our own have close connections with producers and distributors, but do not have similarly close ties with processors and trading companies.

Distribution for Fresh Market

The area planted and production of vegetable soybean in 1987 in the main production areas are shown in Table 1. Both area planted and production have remained on the same level throughout the 1980s. The area planted in Chiba prefecture near Tokyo is decreasing. On the other hand, the Tohoku area in the northern part of Honshu Island, including Iwate prefecture and Akita prefecture, is increasing, because the government has been pushing forward to convert the rice fields to other crops. Niigata prefecture is highest in planted area and production, with half of its production for local consumption or local marketing.

Table 1. Main production areas and production of vegetable soybean in Japan in 1987.

Prefecture	Area (ha)	Production(t)	Quantity shipped (t)
Japan	14,700	116,000	77,000
Niigata	1,630	13,500	7,643
Gunma	1,360	6,610	5,726
Chiba	1,240	12,200	10,534
Iwate	1,090	5,450	3,813
Saitama	698	7,050	5,399
Aomori	608	5,620	3,223
Yamagata	594	6,020	2,656
Fukushima	583	4,280	2,042
Akita	570	5,060	2,653
Shizuoka	559	4,200	2,924
Gifu	468	4,150	3,393
Osaka	319	2,970	2,304
Tokushima	265	2,050	1,890

Source: Ministry of Agriculture and Forestry, Statistics and Intelligence Department.

The main production areas, cropping systems and leading varieties are shown in Table 2. In Japan, vegetable soybean is cultivated year-round. Shimizu city is one of the main production areas in Shizuoka prefecture, with cultivation in winter in heated greenhouses. The leading variety is Sapporo-midori. For shipping, after leaves are removed, the plants are tied up in a bundle and put into wooden crates. They succeeded in distinguishing their products from others, and can get higher prices in the wholesale market. Near Tokyo, the main production areas are Chiba and Saitama prefectures. They also use mainly Sapporo-midori and ship in bundles. The Tohoku and highland areas are Chiba and Saitama prefectures. They supply vegetable soybean during August–September when there is a high demand. They use early to medium-late varieties such as Sapporo-midori (early), Green 75 (early), Yukimusume (medium), Sayamusume(medium), Ezomidori(medium) and Kinshu(medium-late). For shipping, they pick the pods, and then pack them into plastic net bags (300-500 g/bag).

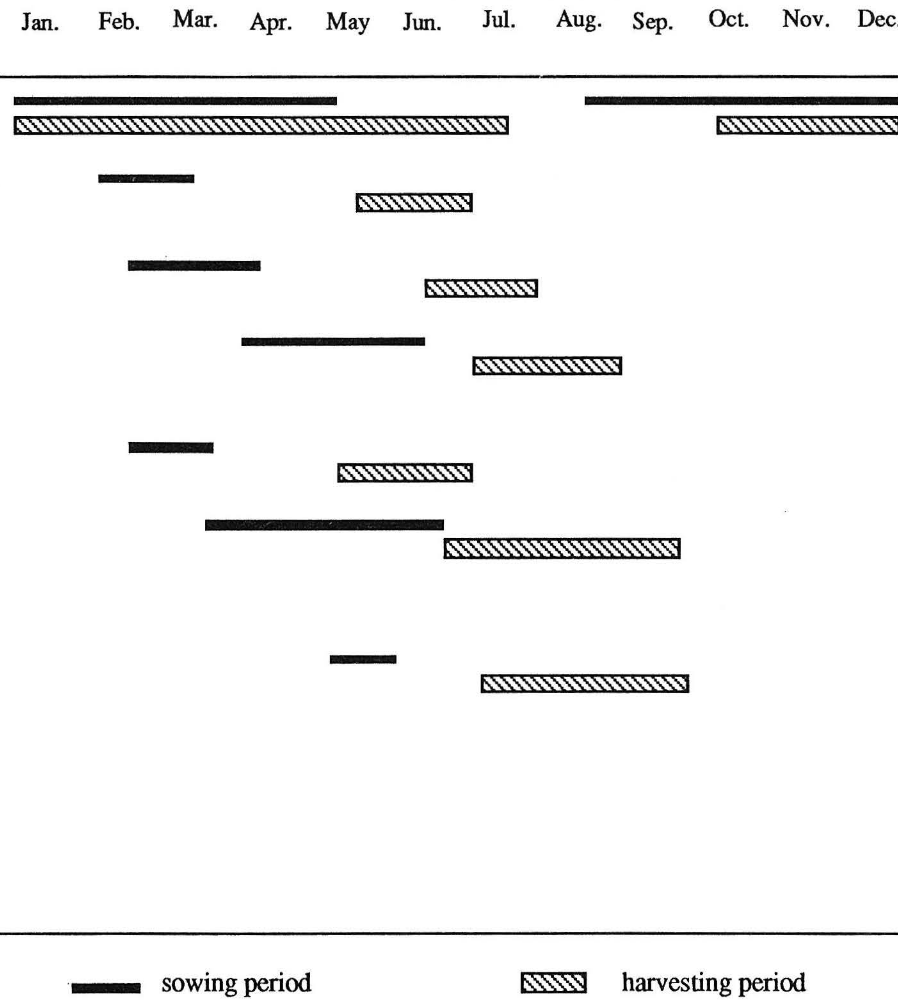
Usually producers sell the products to the wholesale market through an agricultural cooperative. However, producers near the wholesale market sometimes ship their products directly, or through a brokerage dealer, or sell directly to a cooperative store.

Distribution of Seed

Total demand for vegetable soybean seed, estimated by planted area and seeding rate per unit area, is almost 800,000 l. There is considerable self-seed production by local small retail dealers or producers. The self-seed production has been done mainly in medium-late to late-maturity varieties, and at Tohoku and Hokuriku areas including Niigata and Yamagata prefectures. In medium-late or late-maturity at Tohoku and Hokuriku areas, there are many local native varieties, such as Chamame, Aomame, etc. These local native varieties are used for consumption within a limited area. As a result, these self-produced seeds are not distributed through seed companies.

Table 2. Cultivation type and leading variety of vegetable soybean in main production areas of Japan.

District (prefecture)	Cultivation type	Growing period (days)	Leading variety
Shizuoka	Growing in plastic greenhouse	65-110	Sapporo-midori Komamidori
Kanto Area (Chiba, Saitama & Tokyo)	Growing in plastic greenhouse	90-100	Sapporo-midori
	Growing under plastic tunnel	80-90	Sapporo-midori Tengamine
	Normal culture	70-80	Sapporo-midori Sayamusume Tamasudare 2Gou
Kansai Area (Tokushima, Gifu & Osaka)	Growing under plastic tunnel	75-90	Sapporo-midori Yukimusume
	Normal culture	70-80	Yukimusume Sayamusume Fuuki Karikachi
Tohoku Area (Gunma, Akita & Iwate)	Normal culture	80-85	Sapporo-midori Green 75 Hokuei-shirage
			Enzomidori Sayamusume Kitanosuzu Yuusuzume
		90-100	Kinshuu



In Japan, distribution of vegetable soybean seed is handled in two ways, similar to other vegetable crop seeds. One is through the agricultural cooperatives, and another is through the retail dealer shops, with some regional differences.

Seed Production

Seed production of early- to medium-maturity varieties has been carried out mainly at Hokkaido where weather conditions are suitable for production of high-quality seed. On the other hand, seed production of medium-late to late-maturity varieties has been carried out mainly at Tohoku and Hokuriku areas. A considerable amount of seed production of medium-late to late-maturity varieties has been done by local retail dealers and producers. It is not easy to obtain information on this, so details of self-seed production are unclear.

The area devoted to vegetable soybean seed production in Hokkaido by Snow Brand Seed Co. Ltd. is given in Table 3.

Table 3. Area of vegetable soybean seed production in Hokkaido by Snow Brand Seed Co. Ltd.

District	1987	1988	1989	1990	1991
Hokkaido	150 ha	140 ha	130 ha	130 ha	150 ha
Tokachi (%)	35.4	34.6	26.5	26.5	23.1
Kitami (%)	9.4	4.9	4.3	4.3	5.0
Kamikawa (%)	40.9	44.7	48.7	50.0	52.9
Ishikari (%)	14.2	15.9	20.5	19.1	19.0

Future Vegetable Soybean Production

(1) Breeding of tasty new varieties and improvement of cultivation techniques to produce tasty vegetable soybean: As with other vegetable crops, consumer demands for high quality vegetable soybean have become stronger. Therefore quality improvement of vegetable soybean, such as good eating quality, is needed. However, existing early- to medium-maturity varieties are derived from the same materials, so it is difficult to find a clear difference in eating quality between existing varieties. In late-maturity, there are some remarkable materials such as Chamame, Tanba-kuro, etc. On the other hand, some reports show that weather, soil and cultivation conditions affect the quality of vegetable soybean. We therefore need to improve quality by both cultivation techniques and breeding.

(2) Introduction of a machine harvesting system for fresh market and processing: There have been recent experiments in Hokkaido on mechanical harvesting of vegetable soybeans. Machine harvesting will shorten the time from harvest to freezing, thereby contributing to a higher quality product for the consumer.

Vegetable Soybean Varietal Improvement In Japan — Past, Present and Future

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Abstract

Vegetable soybean breeding through hybridization and radiation-influenced mutation has only recently been seriously undertaken in Japan. Local produce is consumed late in the summer; winter requirements are imported from Taiwan, Thailand or New Zealand. Biotechnological breeding techniques will be used in the future to develop a high quality, early-maturing and disease- and insect-resistant variety for both domestic consumption and export.

Introduction

A wide range of vegetable soybean varieties has been cultivated in Japan for many years. The nomenclature is confused, with different varieties having the same name, and identical varieties with different names. There are early or late-maturing varieties because they were used as offerings of The O-bon (16 August) and The Tukimi (9 September) in olden times. Today vegetable soybeans are mostly consumed in July and August, and therefore extremely early or early varieties are used. Fresh vegetable soybeans for winter consumption are imported from Taiwan, Thailand or New Zealand.

Breeding System

Local vegetable soybean varieties such as Hokkaido early-maturity variety or good eating-quality variety (late- or extremely late-maturity) were consumed in the past. More recently, varieties with selected qualities were crossed with local varieties (extremely early or early variety). Vegetable breeding is done by hybridization and pedigree selection, and through mutation by radiation. Almost all varieties are produced by private seed companies, with a few varieties being produced through national or prefectural experiment stations (public). Prefectural experiment stations are conducting breeding, especially for disease resistance. Future research will emphasize selection for high quality and insect resistance through modern biotechnology (e.g. using embryo culture for species hybridization).

The characteristics of important varieties in Japan are presented in Table 1.

Breeding Objectives

The breeding objectives are as follows:

(1) Early maturity (or nonseasonal): 30-40 days after flowering (about 90 days after seeding);

(2) High quality: (a) Morphological characters: Pod size (large), Pubescence color (white), etc.; (b) Chemical composition; sweetness (carbohydrate content), etc. (Fig. 1);

Table 1. Main vegetable soybean varieties.

Variety	Breeding system	Maturity	Pod size	Pubescence color	Seed coat color	Notes
Datacha	Local Variety	Extremely late	Medium	Brown	Brown	Tohoku local variety (sweetness)
Krosai-chamame	"	"	Large	"	"	Niigata local variety
Hiradoko	"	"	"	"	Green	Tohoku local variety (flat seed)
Tanbaguro	"	"	"	"	Black	Kinki local variety (largest seed)
Okuhara 1 gou	Pedigree	Extremely early	Medium	Brown	Yellow	Hokkaido local variety
Wase Midori	"	Medium	Large	"	Green	"
Tokyo Wase	"	Late	"	White	Yellow	Kantou local variety
Sapporo Midori	Cross	Early	Large	White	Light green	Private (seed company)
Yukimusume	"	Early-medium	"	"	"	"
Mosono Green	"	"	"	"	Yellow	"
Kita no Siki	"	"	"	"	Light green	"
Green-75	Pedigree	Extremely early	"	"	"	"
Echigo Musume	"	Late	"	"	Green	"
Hatu Musume	"	"	"	"	Light green	"
Iwa-mame-kei 1	Mutation (radiation)	"	"	"	Green	Breeding in Iwate Pref., Agricult.
Experiment Station						
Iwa-mame-kei 4	"	Medium-late	"	"	Light-green	"

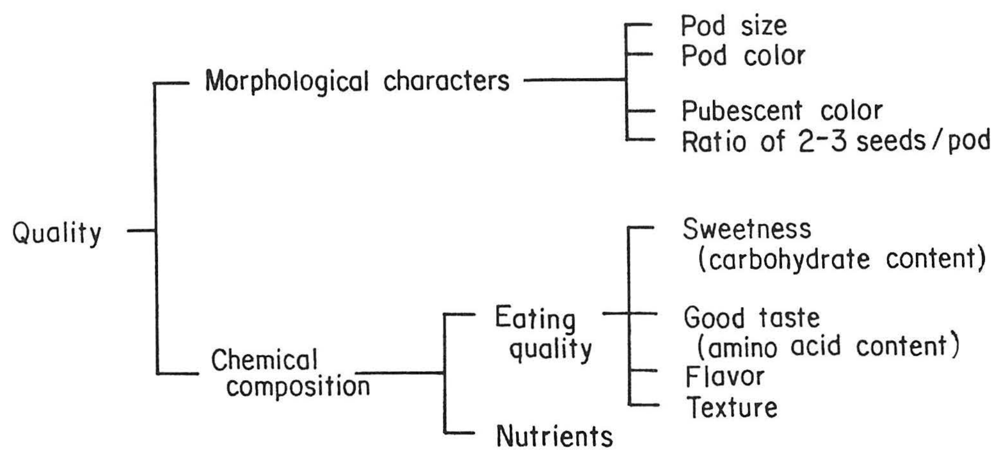

Fig. 1. Quality components of vegetable soybean.

(3) Diseases and insect resistance: soybean mosaic virus (SMV), Phytophthora rot, soybean cyst nematode (SCN), etc.

Genetic Resources

(1) Early maturity

(a) Summer type soybean varieties (e.g. Hokkaido varieties, Maturity group 00-III (USA) (low photoperiod sensitivity varieties or high sensitivity to temperature varieties)

(b) Nonseasonal varieties (e.g. Southeast Asian varieties — local varieties from low latitude, Vali No. 3)

(2) High quality

(a) Pod size: large (e.g. Yuuzuru (Hokkaido), Enrei (Nagano) Tanbaguro (Hyougo))

(b) Pod color: fresh green (seed color yellow or green)

(c) Pubescence color: white (many)

(d) Ratio of 2-3 seeds/pod: (narrow leaflet varieties)

(e) Sweetness: high carbohydrate content (seed-color of brown or black varieties)

(f) Good taste: amino acid content undecided

(g) Flavor: cis-jasmine, etc., undecided (brown seed-color varieties have bad flavor)

(h) Texture: undecided (large flat seed varieties: e.g. Hiradoko shitashi-mame, etc.) (Watanabe et al. 1989; Watanabe and Nagasawa 1990)

(3) Disease and insect resistance

(a) Soybean mosaic virus (SMV): A, B, C, D-strain resistance (Suzuyutaka, Hourei, etc.)

(b) Soybean dwarf virus (SDV): Immune tolerance? (Turukogane, Adams, etc.) (Banba 1988; Hashimoto 1985)

(c) Phytophthora rot: no screening in Japan

(d) Soybean cyst nematode: race 3, 5 resistance (Peking, PI90763, etc.)

(e) Insects: Soybean pod borer (*Leguminivora glycinivorella*); less or glabrous varieties are resistant; Soybean pod gall-midge (*Asphondylia* sp.); dense-pubescence varieties are resistant; bugs (souden-daizu, himesirazu, etc.).

Future Prospects

Our goal is a high yield of 9-10 t/ha. Also, we are aiming at higher quality (chemical composition) and greater safety (low levels of insecticide). These may be exported for consumption in other countries because until recently no suitable soybean strains have been bred in Japan. Our strains do not have lipoxygenase (Kitamura 1984) and therefore they could be used as fresh beans in salad or could be used instead of peas.

References

Banba, H. 1988. Utilization of genetic resources for soybean dwarf virus in soybean breeding. Crop Genetic Resources of East Asia: IBPGR, 105-111.

Hashimoto, K. 1985. Breeding for soybean virus resistance. *In*: Soybean in Tropical and Subtropical Cropping Systems: AVRDC, 151-157.

Kitamura, K. 1984. Biochemical characterization of lipoxygenase lacking mutants, L-1-less, L-2-less and L-3-less soybeans. Agric. Biol. Chem., 48, 2339-2346.

Watanabe, I., and Nagasawa, T. 1990. Appearance and chemical composition of soybean seeds in germplasm collection of Japan. Japan Jour. Crop Sci., 59(4), 661-666.

Watanabe, I., Sato, M., Nagasawa, T., Okabe, A., and Sakai, S. 1989. Chemical composition and appearance of soybean seeds in germplasm collection of Japan. Misc. Publ. Tohoku Natl. Exp. Stn., 9, 21-131.

Varietal Improvement of Vegetable Soybean in Taiwan

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Abstract

Varietal improvement of vegetable soybean in Taiwan dates back to the early 1950s. Used domestically as a shelled green bean, vegetable soybean became a major frozen export commodity in the 1980s. Introduction of improved varieties, mainly from Japan, resulted in the use of "Shih Shih" a multipurpose variety, and later Tzurunoko and Ryokkoh became the major export varieties. Varietal improvement research was systematically initiated at AVRDC and the Kaohsiung District Agricultural Improvement Station (DAIS) from 1985 with support from the Council of Agriculture in Taiwan. In 1987 Kaohsiung DAIS released an AVRDC pureline selection from Taisho Shiroge as the first vegetable soybean variety formally released in Taiwan and named it Kaohsiung No. 1. In 1990 Kaohsiung No. 1 (KS # 1) occupied 84% of the total vegetable soybean area. Hybridization and selection to improve KS # 1 using pedigree, SSD and backcross methods are in progress at AVRDC and Kaohsiung DAIS. Improved varieties with better quality adapted to Taiwan and the tropics could be forthcoming. Future directions of vegetable soybean varietal improvement are discussed.

Introduction

Vegetable soybean (*Glycine max* (L.) Merrill) is defined as those which are harvested after the R6 and before R7 growth stage (Fehr et al. 1971) while the pod is still green and the seeds have developed to fill 80–90% of the pod width. Historically vegetable soybean, mao dou, is recognized in China for its medicinal value. Prior to 1975 the total area and production of vegetable soybeans in Taiwan was negligible (see Shui-Ho Cheng, these proceedings). In Taiwan, the beans are customarily shelled from the pod (Shanmugasundaram et al. 1989) and they are marketed as fresh beans. Frozen beans are becoming popular in Taiwan through the supermarkets.

Traditionally vegetable soybeans are used in Japan as a snack during tea time or eaten with beer in the summer (Shinohara 1989). However, tradition has changed. Now there is a year-round demand for vegetable soybean. Domestic production in Japan cannot meet the demand. As a result, Japan has to import vegetable soybeans. Taiwan has rapidly developed the know-how in vegetable soybean production, and exports most of its production to Japan. From a negligible area and production level in the early 1970s, the vegetable soybean area and production in Taiwan increased steadily to reach the present level of around 10,000 ha annually (Shanmugasundaram et al. 1990). The varietal improvement research addressed the needs of the changing industry and export needs, and is reviewed in this paper.

Research Up to 1980

From 1950 to 1980, vegetable soybeans were grown primarily in the Pingtung-Kaohsiung area in southern Taiwan during the fall season, and to a lesser extent in spring and summer. A few farmers in the Chia-Nan and Taichung areas also grew them for the local market.

In 1957, Taiwan introduced a multipurpose soybean variety "Jikkoku" from Japan (called "Shih Shih" in Taiwan). It was used both as a grain and as a vegetable soybean (Shanmugasundaram 1979).

From a screening of introduced germplasm in 1965, Cheng and Chan identified 13 accessions as suitable for use as vegetable soybeans. Among them PI 153210 and PI 179823 were considered the best. The major criteria used for selection were large seed size (25 or more g/100-seed weight) and fairly good adaptability to Taiwan's agroclimatic conditions in spring, summer and autumn seasons. However, detailed multilocational trials and consumer quality were not determined, and none of the selections became popular.

Due to the lucrative demand from Japan in the early 1970s, the frozen food manufacturers and the intermediaries in Taiwan introduced a number of vegetable soybeans primarily from Japan and evaluated them for their adaptability specifically for the southern part of Taiwan.

The variety Tzurunoko (commonly referred to by farmers as 205) performed satisfactorily. A few years later, another variety Ryokkoh (popularly referred to by farmers as 305) was also acceptable to the farmers, processors and the importers. Both varieties were introductions from Japan. Ryokkoh had brighter green pod color, better flavor, and larger seed size than Tzurunoko. Both varieties were cultivated by the farmers. The seeds of both varieties for planting were imported from Japan while the frozen pods were exported from Taiwan to Japan.

Since the area grown to vegetable soybean was insignificant, the quantity of seeds required was also negligible. Therefore, there was little incentive on the part of private seed companies in Taiwan to develop improved vegetable soybean varieties. Neverthless "Known You" Seed Company did list a variety called "Zen Wu No. 1." But it was neither popular with farmers nor with the processors. It is probably used by home gardeners.

A total of 21 soybean varieties were released by District Agricultural Improvement Stations, Taiwan Agricultural Research Institute and local·universities from 1956 to 1980 but none of them were vegetable soybeans.

At AVRDC from 1976 to 1978, 200 accessions from the germplasm collection with large seed size were screened in the field to select potential vegetable soybeans. Based on seed size and green bean yield five accessions were selected and evaluated during spring, summer and autumn seasons in 1979. Among them G 8547 (PI 200538) with gray pubescence had 42 g for shelled 100-bean weight and could be harvested in 93 days compared to Shih Shih's 24 g for 100-bean weight and was harvested in 66 days (Table 1).

In 1980 four accessions were compared with Shih Shih, Tzurunoko, and Zen Wu # 2 (from "Known You"), in spring, summer and autumn seasons. G 8285 was better than the check variety Shih Shih in terms of 100-seed weight. However, its pubescence color was tawny which is unacceptable to the market (Table 2).

Research Since 1981

With the gradual increase in vegetable soybean area, AVRDC and Kaohsiung DAIS recognized the growing importance of the crop. The varietal improvement research at AVRDC was strengthened by allocating more resources. The Council of Agriculture (COA) in Taiwan in 1985 approved and funded a special vegetable soybean research project at AVRDC and the Kaohsiung DAIS. As of 1990, a total of US$302,198 has been provided by the COA specifically for vegetable soybean research.

The research activities of the above project included the following:

(1) Evaluation of large-seeded germplasm for vegetable soybean production in Taiwan.

(2) Introduction and screening of Japanese vegetable soybean varieties for southern Taiwan.

(3) Collaboration with Kaohsiung DAIS in initiating vegetable soybean regional yield trials and district trials for variety evaluation in Taiwan.

(4) Help to release new vegetable soybean cultivars to replace Tzurunoko and Ryokkoh.

(5) Introduction of harvesting machine for vegetable soybean to reduce cost of production.

(6) Development of quality evaluation methodologies for processing vegetable soybeans.

(7) Investigation of cultural practices, fertilization and plant population density for vegetable soybean in southern Taiwan.

(8) Physiological studies on abiotic stresses on yield and quality of vegetable soybean.

(9) Breeding tropical vegetable soybean (AVRDC 1991).

Table 1. Yield, seed size and per day productivity of some promising vegetable soybean accessions during spring and summer seasons, 1979.

Acc. No.	Name or PI No.	Yield/ha[a] (kg)	100-seed wt (g)	Days to Maturity (DM)
G 8708	PI 203403	4312 AB (5218)	44 B	95 AB
G 8707	PI 203405	3787 B (4895)	38 B	102 A
G 8547	PI 200538	3851 C (4449)	42 B (59)	93 BC
G 38	Shih Shih	2044 D (5306)	24 C (37)	66 D
Mean		3381	41	89
CV		3	7	4

[a]Green bean yield; values in parentheses are for spring season and the differences between the varieties are insignificant. Values followed by the same letter within a column are not significantly different at 0.05% level of *P* according to Duncan's Multiple Range Test (DMRT).

Table 2. Yield potential of the vegetable soybean selections.

Acc.	PI No.	Yield (t/ha)[a]			Yield/ha/day (kg)			Days to maturity			100-seed weight		
No.	or name	Feb.	July	Sept.	Feb.	July	Sept.	Feb.	July	Sept.	Feb.	July	Sept.
G 8285	165672	8.2a	9.4a	6.9ab	96	112	89	86	84	77	56	55	60
G 9948	Zen Wu #2	7.1a	3.6b	2.6c	99	54	111	72	66	71	51	58	63
G 9053	Tzuronoko	6.9a	10.1a	2.5c	91	144	37	76	70	71	57	56	55
G 38	Shih Shih	3.1b	11.5a	7.9a	39	165	36	79	70	71	34	34	37

[a]Green pod yield; values followed by the same letter are not significantly different from each other at 0.05 *P* according to DMRT.

Screening Large-Seeded Germplasm

The objective was to develop vegetable soybeans acceptable to the Japanese market. The following characteristics are desired for the Japanese consumers: the pods and seeds should be large (the dry weight of 100 seeds should be 30 g or more; a 500-g frozen pod packet should contain 175 pods or less); the pods should have two or more seeds; one-seeded, malformed, yellow or damaged pods are unacceptable; the pod and seed color should be bright green; pubescence on the pod should be sparse and gray; gray or light brown hilum color is required; good flavor, aroma, and texture are needed; slightly sweet taste is preferable while oily taste is undesirable; short cooking time is preferred (Shanmugasundaram et al. 1989; see also Cheng; Tsou and Hong, these proceedings). The quality should be similar to or better than Tzurunoko or Ryokkoh which have become standards over the years.

A number of American, Japanese, Korean, Chinese and Philippines soybean introductions with large seeds were selected from the germplasm and evaluated for their potential in Taiwan. Among the 142 accessions evaluated in 1982 eight accessions were selected based on the above characteristics. Seven of the eight entries were evaluated in 13 locations in spring and autumn seasons in Taiwan in 1983. Observations were collected on the following traits:

(1) Days to first flowering (R_1).

(2) Days to 50% flowering.

(3) Days to complete flowering (R_2).

(4) Days to harvesting (R_6).

(5) Plant height at R_1 (cm).

(6) Plant height at R_6 (cm).

(7) Number of plants harvested per plot.

(8) Number of pods per plant (use 10 sample plants):

- 8.1 Number of 1-seeded pods,
- 8.2 Number of 2-seeded pods,
- 8.3 Number of 3-seeded pods,
- 8.4 Number of 2- and 3-seeded pods.

(9) Percent of 2- or more seeded pods.

(10) Pod weight per plant (use 10 sample plants).

- 10.1 One-seeded pod weight,
- 10.2 2-seeded pod weight,
- 10.3 3-seeded pod weight,
- 10.4 2- and 3-seeded pod weight.

(11) Percent of 2- or more seeded pod weight.

(12) Biomass production per hectare (fresh weight, tons):

- 12.1 Whole plant weight,
- 12.2 Stem and green pod weight,
- 12.3 Green pod weight.

(13) Number of standard pods per kilogram.

(14) Seed weight per kilogram of pod.

(15) 100-seed weight (g).

(16) Harvest index (HI): Calculated from formula:

HI = Economic yield/Biological yield × 100 = Green pod weight/Whole plant weight × 100.

(17) Daily production rate (DPR): Calculated from formula:

DPR = Green pod yield/Days to harvest.

The mean graded pod yield, the variety adaptation (regression coefficient) and the standard errors are given in Table 3. Although the yield of the new selections was significantly higher than the checks, other quality characteristics were unacceptable for the Japanese market and therefore all of them were considered unsuitable for production in Taiwan.

Table 3. Mean pod yield, variety adaptation (regression coefficient b), coefficient of determination (r^2) and mean square due to deviation from regression (S^2d) for nine vegetable soybean varieties grown in 13 locations in Taiwan in spring and autumn seasons in 1983.

Entry No. or name	Original name	Source	Mean pod yield (t/ha)[a]	b	r^2	S^2d
AGS 187	Y-386	Korea	12.7 a[a]	0.92	0.75	3.01
AGS 190	Vesoy # 4	Philippines	11.9 ab	1.07	0.80	3.30
AGS 188	PI 157424	Korea	11.6 ab	0.88	0.70	3.57
AGS 185	Houjaku	Japan	11.4 ab	1.04	0.73	4.24
Ryokkoh (ck)	Ryokkoh	Japan	11.4 ab	0.75	0.57	4.62
AGS 186	Yoshida-1	Japan	11.1 ab	0.81	0.64	4.09
Tzurunoko (ck)	Tzurunoko	Japan	10.3 b	0.97	0.54	8.79
AGS 189	Disoy	USA	10.2 b	1.37	0.35	37.63
AGS 191	BPI # 4	Philippines	10.0 b	0.99	0.85	1.96

[a]Values followed by the same letters are not significantly different from each other at 0.05 *P* level according to DMRT.

From 1980 to 1983, AVRDC received 51 vegetable soybean varieties from 10 seed companies in Japan. Based on an observational trial varieties Tancho, Ryokukou, Nakate Kaori and a pureline selection from Taisho Shiroge were selected for further evaluation.

In 1984 spring season, 54 introductions and two checks, Tzurunoko and Ryokkoh, were evaluated using a 7×8 lattice design with two replications. Among the 54 entries evaluated, six were selected and compared against the checks in a regional yield trial during spring, summer and autumn seasons in 1985 and 1986. The pod and seed quality of AGS 292 (the pureline selection from Taisho Shiroge) was acceptable to the processing company and the Japanese consumers. The yield and a few other traits of four entries along with checks are given in Table 4.

AGS 292 was recognized as the best selection based on the results of the regional yield trials by the Kaohsiung DAIS. The variety release committee approved the release of AGS 292 as Kaohsiung No. 1 in 1987. The mean graded pod yield of AGS 292 compared to Tzurunoko and Ryokkoh is given in Table 5.

The area planted to Kaohsiung No. 1 in the spring and autumn seasons in 1988, 1989 and 1990 are 45.5 and 56%; 72 and 65%; and 82 and 84% of the total vegetable soybean area respectively. The total value of Kaohsiung No. 1 exported to Japan in 1990 hit a record of about US$63 million.

Table 4. The best four vegetable soybean selections from 56 evaluated in 1984 at AVRDC.

Entry No. or name	Graded pod yield (t/ha) Spring	Graded pod yield (t/ha) Summer	Pods/kg[a] Spring	Pods/kg[a] Summer	100 seed wt (g) Spring	100 seed wt (g) Summer
AGS 293	10.7	10.1	284	381	86	74
AGS 294	10.5	7.6	359	500	71	54
G 6852	12.3	10.6	304	557	81	52
Ryokkoh (ck)	11.5	10.8	284	444	88	61
AGS 292	8.8	10.6	430	507	51	59
Tzurunoko (ck)	10.3	9.3	425	407	63	60
Mean (58 entries)	9.2	8.8	453	516	58	54
CV	2.3	2.8	8.1	17	8	8
LSD (0.05)	3.9	4.1	73.5	177	9	9
Maximum	13.5	11.0	722	811	88	76
Minimum	5.1	4.0	283	274	34	34

[a]The desirable number for Japanese market is 350 or less/kg.

Table 5. Mean pod yield of AGS 292 in regional yield trial compared to local checks.

	Graded pod yield (kg/ha)								
	Spring			Summer			Autumn		
Year	292	205[a]	305[b]	292	205	305	292	205	305
1985 (4)[c]	5627[d]	4971	4047 (2)	7391	6932	6088 (3)	7306	5587	5986
1986 (3)	7696	6540	5461 (2)	3234	2992	2559 (3)	3506	3172	3444

[a]Tzurunoko.
[b]Ryokkoh.
[c]Values in parentheses refer to number of locations.
[d]The yield of 292 is significantly different from 205 and 305 in all three seasons.

Breeding Strategy

The objective is to improve Kaohsiung No. 1. The characteristics to be improved are:

(1) Yield potential as good or better than Kaohsiung No. 1 (KS # 1).

(2) Ease of harvest similar to KS # 1.

(3) Pod color and seed color similar to Ryokkoh.

(4) The texture expressed by its hardness should be similar to Tzurunoko or Ryokkoh.

(5) Sweetness should be similar to KS # 1.

(6) Umami as used to describe the flavor, should be similar to KS # 1.

(7) Aroma similar to KS # 1.

(8) Duration from beginning to end of picking should be longer than KS # 1.

(9) Absence of spotting on the pod.

(10) Suitable for mechanical harvest.

From 1982 to 1990 a total of 173 crosses and backcrosses were made to combine the above characteristics. A backcross or modified backcross is used to maintain the desired seed size of vegetable soybean when crosses are made between tropical grain types with temperate vegetable soybeans. The number of backcrosses required to increase the seed size and pod size of the resulting progenies from crosses between tropical grain and temperate vegetable soybean depends largely on the seed size of the nonrecurrent tropical grain type. If the seed size is less than 20 g then two or more backcrosses are required. Bravo et al. (1980) reported that the number of F_2 plants needed at 0.10 probability to recover 0.5% frequency of desirable seed size is 450. However, the seed size differences of the parents used in their study were not large. Therefore, the F_2 population size is rather conservative.

The second strategy is to introduce narrow leaflet gene, lnln, into the new vegetable soybeans. Narrow leaflet is associated with a higher number of three- and four-seeded pods. Therefore, by introducing lnln gene the frequency of two- or more seeded pods will increase. However, caution should be exercised to see that the narrow leaflet is large enough to avoid sunscald injury or pigmentation on the pod.

It is equally important to understand the genotypic and environmental variations and their interactions so that the potential to select for wide adaptability can be ascertained. This is the third strategy. The yield and other traits of a few promising selections in spring, summer and autumn seasons are shown in Tables 6, 7 and 8.

Table 6. Promising selections from the advanced yield trial of vegetable soybeans in spring season, 1988.

Entry No.	Parents	Graded pod yield (t/ha)	Total pod yield (t/ha)	Days to maturity	100-seed weight (g)	No.of accept. pods/ 500 g	Harvest index
AGS 292	Taisho Shiroge Selection	7.5 a[a]	11.9	77	74	157	31
G 9053	Tzurunoko	6.9 ab	12.0	82	74	181	26
GC 83006-7	PI 157424 × Ryokkoh	6.8 abc	10.8	84	82	166	27
AGS 294	Imperial	6.3 bcd	10.3	82	77	170	29
GC 84136-P-4-1-8	Ryokkoh × Mikawajima	6.2 bcd	13.0	91	72	178	21
GC 84134-P-9-3-1-5-1	Ryokkoh × Disoy	6.2 bcde	12.6	86	72	209	22
GC 83006-15	PI 157424 × Ryokkoh	6.0 bcde	10.4	84	76	189	24
G 10134	Ryokkoh	5.7 cdef	12.1	86	81	174	22
LSD 0.05			1.2	1.8	3.1	16.3	

[a]Values followed by the same letters are not significantly different from each other at 0.05 *P* level according to DMRT.

Variation in graded pod yield attribution to seasons was 31%, and 22% was due to genotype and a major portion, 46%, was due to G×E interaction. The results suggest that there is sufficient genotypic variation to select vegetable soybeans. However, the G×E interaction is a major factor and it may therefore be necessary to select genotypes for specific seasons.

For 100-seed weight, on the other hand, genotypic variation dominated (56%) and the G×E interaction was only 17% while the variation due to season was 28%. Compared to the 100-seed weight of 63–68 g (on fresh basis) for the check varieties, the selections had a 100-seed weight of 72–74 g.

The fourth strategy is to identify appropriate selection criteria to select vegetable soybeans. Bravo et al. (1980) and Frank and Fehr (1981) reported that there is a highly significant correlation between pod length or pod width and 100-seed weight. At AVRDC, the yield trial data from 1990 spring and autumn seasons were used to determine the relationship between 100-seed weight (dependent variable) and one of the following as independent variables: number of one-seed pods, number of two-seed pods, and length and width of two-seed pods. Among them only the length and width of two-seeded pods have a significantly close relationship to 100-seed weight. The regression equation for them is given below:

100-seed weight and length of two-seeded pods:

$Y = -0.8568 + 13.6041\times$ (length of two-seeded pods)

100-seed weight and width of two-seeded pods:

$y = 21.1135 + 33.9291\times$ (width of two-seeded pods)

Table 7. Promising selections from the advanced yield trial of vegetable soybeans in summer season, 1988.

Entry No.	Parents	Graded pod yield (t/ha)	Total pod yield (t/ha)	Days to maturity	100-seed weight (g)	No.of accept. pods/ 500 g	Harvest index
GC 83011-25	Vesoy # 4×KS # 8	6.4 a[a]	8.6 ab	82	56	254	33
GC 84136-P-4-1-8	Ryokkoh×Mikawajima	5.0 b	7.5 abc	78	69	178	33
GC 84136-P-4-1-4-2	Ryokkoh×Mikawajima	4.9 b	9.0 a	80	62	211	25
GC 83006-25	PI 157424×Ryokkoh	4.9 b	8.5 ab	82	79	196	26
GC 83005-9	PI 157424×KS # 8	4.9 b	8.9 a	81	55	276	21
G 9053	Tzurunoko	4.2 bcd	6.2 cd	78	63	222	32
G 10134	Ryokkoh	3.9 bcd	6.6 bcd	72	60	227	26
AGS 292	KS # 1	3.3 cde	4.8 d	72	57	209	32
LSD (0.05)				1.3	5.5	13	

[a]Values followed by the same letters are not significantly different from each other at 0.05 *P* level according to DMRT.

Table 8. Promising vegetable soybean selections from advanced yield trial in autumn season, 1988.

Entry No.	Parents	Graded pod yield (t/ha)	Total pod yield (t/ha)	Days to maturity	100-seed weight (g)	No.of accept. pods/ 500 g	Harvest index
GC 83011-35	AGS 190×KS # 8	6.9 a[a]	8.7 ab	74	62	260	40
GC 83005-9	PI 157424×KS # 8	6.3 ab	9.7 a	74	50	266	31
GC 84136-P-4-1-4-2	Ryokkoh×Mikawajima	6.3 ab	9.3 ab	74	59	205	36
GC 84136-P-4-1-8	Ryokkoh×Mikawajima	5.6 bc	9.0 ab	72	65	182	33
GC 83006-25	PI 157424×Ryokkoh	5.1 cd	8.5 ab	71	65	226	30
G 10134	Ryokkoh	4.1 de	6.6 de	68	64	227	32
G 9053	Tzurunoko	3.9 e	6.0 de	74	66	211	36
AGS 292	KS # 1	3.7 e	5.5 e	70	58	195	39
LSD (0.05)				1.2	4.5	14.3	

[a]Values followed by the same letters are not significantly different from each other at 0.05 *P* level according to DMRT.

The regression of 100-seed weight with length and width of two-seeded pods was highly significant (Fig. 1 and 2).

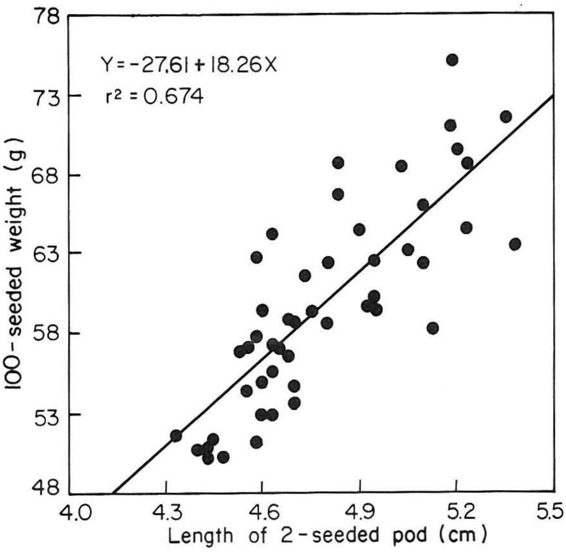

Fig. 1. Regression of 100-seed weight on length of 2-seeded pod.

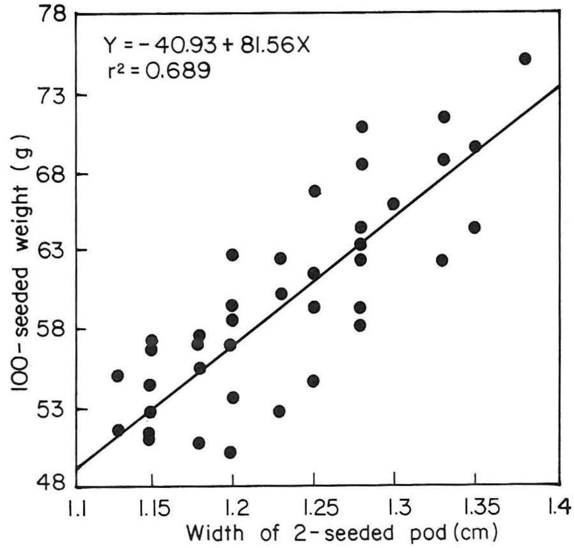

Fig. 2. Regression of 100-seed weight on width of 2-seeded pod.

The size of the primary leaf and its association with 100-seed weight also appears to be strong and could be used as a selection criterion but it requires further study to confirm the preliminary findings (Sirikul et al. 1990).

Finally the quality characteristics are closely scrutinized, with assistance from our biochemists (see Tsou and Hong, these proceedings). Selection in the early generations are for seed size and adaptability. At the intermediate yield trial stage the selections are screened for quality characteristics.

Breeding Methods

Depending upon the parents used in the hybridization the breeding method differed. Whenever both parents used were vegetable soybeans as in the case of Tzurunoko×Kaohsiung No. 1 or Blue Side×Kaohsiung No. 1 either pedigree method or SSD method is used. Selection for bacterial pustule and downy mildew as well as quality is given priority.

In instances when the cross involved a tropical grain type and a temperate vegetable type, as for example the cross between Kaohsiung No. 10×Kaohsiung No. 1 or Kaohsiung No. 1×Tropical then, as discussed earlier, a backcross method followed by pedigree selection is used. Therefore, at present a pod length of ≥ 5.0 cm and a pod width of ≥ 1.4 cm are used as selection criteria.

In 1989, additional new introductions from Japan have been received and evaluated. From them, Blue Side and Shirofumi have been selected for inclusion in the breeding program (Table 9).

Vegetable Soybean Plant Type

Based on the experience gained from the research on vegetable soybean a close-to-ideal plant type for vegetable soybean in the tropics (including Taiwan) should have the following characteristics:

(1) Nonlodging strong stem with good root system.

(2) Delayed flowering ≥ 40 days.
(3) Ten to fourteen nodes.
(4) Fewer branches.
(5) Large narrow leaflets preferred.
(6) Longer R_6 to R_7 period.
(7) Less sensitive to photoperiod and temperature.
(8) With 400,000 plants/ha about 15–20 pods/plant.
(9) Pod width of ≥ 1.4 cm.
(10) Pod length of ≥ 5.0 cm.
(11) Predominantly (≥ 75 %) two- or more seeded pods.
(12) Bright green pod and seed coat color.
(13) Gray pubescence.
(14) Gray or light brown hilum.
(15) Easy to strip pods.
(16) Pod clearance from soil at least 10 cm.
(17) Resistance to bacterial pustule and downy mildew.
(18) Tolerant to soybean rust.
(19) Dry weight of 100 seeds ≥ 30 g.
(20) Free from undesirable pigmentation and/or spots on stem or pods.
(21) Preferably lipoxygenase null.

As more experience is gained from the research the qualifications for the ideal plant type will be appropriately modified.

Table 9. Promising selections from vegetable soybean advanced yield trial, spring season, 1989.

Entry	Yield (t/ha) standard pod weight	Days to maturity	Two-seeded pod		100-seed weight (g)	No. of standard pods/500 g
			Length (cm)	Width (cm)		
Blue Side	9.5	91	5.2	1.4	79.7	183
GC 84136-P-4-1-8	8.8	91	5.4	1.4	81.0	163
Shirofumi	8.7	78	4.5	1.3	66.3	209
Tzurunoko (ck)	8.6	82	4.9	1.4	68.5	194
KS # 1 (ck)	7.3	76	5.1	1.3	55.6	203
Ryokkoh (ck)	6.2	82	5.1	1.4	68.5	195
Mean	8.0	8.07	4.88	1.31	67	197
CV	8.3	0.07	3.48	3.92	3.7	7.5
LSD (0.05)	0.95	-	0.24	0.07	3.56	21.2

Research at Kaohsiung DAIS

Since the early 1980s Kaohsiung DAIS tried to make pureline selections from Tzurunoko (205), Ryokkoh (305) and Yukinoshita. Although there were differences between purelines, they were not significant enough to promote them.

Through the COA project the cooperation between Kaohsiung DAIS and AVRDC on vegetable soybean research was strengthened. Advanced yield trials, regional yield trials and district trials were conducted. The final outcome of this effort was Kaohsiung No. 1, the first vegetable soybean variety approved and released by Kaohsiung DAIS.

In the meanwhile AVRDC provided a number of F_1 seeds from crosses made at AVRDC. F_1 generation and succeeding generations were planted and pedigree selections were made by Kaohsiung DAIS. AVRDC also provided selections from a number of different inbred generations to Kaohsiung DAIS for selection. The selections were designated as Kaohsiung Vegetable Soybean (KVS). Based on the data from different locations and seasons KVS 39 and KVS 124 have been selected and currently being proposed for release to the farmers. The regional yield trial data from selected locations are given in Table 10 and 11.

Table 10. Regional yield trial at three locations, autumn 1989.

Entry	Days to maturity	No. of standard pods/500 g	Standard pod		Yield (t/ha)	
			Length (cm)	Width (cm)	Standard pod wt	Total plant wt
Kaohsiung Area						
KVS 39	76	162	5.8	1.4	7.0	18.0
KVS 124	81	132	5.9	1.5	8.2	18.9
G 10134	71	130	5.9	1.6	5.9	14.8
AGS 292	71	129	5.8	1.4	8.0	15.3
LSD (0.05)		17.4			0.9	1.9
Pingtung Area						
KVS 39	72	148	5.5	1.4	8.8	19.1
KVS 124	73	134	5.5	1.4	8.0	16.0
G 10134	68	130	5.8	1.6	6.7	14.0
AGS 292	68	140	6.0	1.5	7.9	14.5
LSD (0.05)		10.8			1.2	2.1
AVRDC						
KVS 39	76	200	5.2	1.4	2.2	10.2
KVS 124	76	172	5.6	1.5	2.8	11.5
G 10134	72	177	5.3	1.5	1.9	9.5
AGS 292	66	186	6.4	1.5	2.1	8.6
LSD (0.05)		8.0			0.7	1.6

From 1988 onwards Kaohsiung DAIS began making their own cross combinations. The quality evaluations of selections are being conducted at AVRDC (Anon. 1987).

Future Directions

Due to increases in cost of production, the vegetable soybean industry in Taiwan is under considerable pressure. Retaining the high yield potential and other desirable characteristics of Kaohsiung No. 1, the objective should be to improve and sustain the quality, both physical and chemical, in order to remain competitive for export to Japan. Taiwan's vegetable soybean should be synonymous with excellent quality. Selection criteria and screening techniques for quality assessment need to be fine-tuned.

Disease resistance will be emphasized to avoid undue pesticide residue problems that will inhibit export. At the same time, it will help reduce cost of production by reducing the use of chemicals and labor. Furthermore it will enhance the quality.

In addition to export market, there is growing demand for vegetable soybean in the domestic market in Taiwan as shown by the increase in consumption of shelled beans from 4700 t in 1984 to 14,000 t in 1989. Such domestic markets may likely expand in other neighboring countries as well. Therefore, varieties and management techniques could also be directed toward shelled beans for the fresh and frozen market.

Table 11. Regional yield trial at three locations, spring 1990.

Entry	Days to maturity	No. of standard pods/500 g	Standard pod		Yield (t/ha)	
			Length (cm)	Width (cm)	Standard pod wt	Total plant wt
Kaohsiung Area						
KVS 39	86	169	5.3	1.4	6.7	20.2
KVS 124	86	165	5.3	1.4	7.3	20.4
G 10134	74	163	5.8	1.5	5.9	20.3
AGS 292	74	148	6.0	1.4	7.1	20.2
LSD (0.05)		11.0			0.9	1.7
Tainan Area						
KVS 39	76	185	4.9	1.3	4.6	17.1
KVS 124	84	163	5.5	1.4	7.3	20.7
G 10134	70	173	5.7	1.5	2.8	14.4
AGS 292	63	161	5.7	1.5	4.1	14.1
LSD (0.05)		16.8			1.6	3.6
AVRDC						
KVS 39	76	150	5.6	1.5	2.3	20.3
KVS 124	83	147	5.5	1.5	3.2	18.0
G 10134	69	153	6.0	1.6	3.7	18.6
AGS 292	68	128	5.7	1.7	5.7	18.1
LSD (0.05)		8.2			0.4	1.3

Taiwan's entrepreneurs are looking at alternative strategies for vegetable soybean production for a number of reasons. The vegetable soybean production is being moved to neighboring cheaper locations. Therefore, AVRDC will try to help farmers in those regions produce quality vegetable soybeans. Such efforts will not only promote vegetable soybean for export but also is expected to promote domestic consumption of the product. Thailand, Philippines, Indonesia and Malaysia are target countries.

In the course of tropicalizing the vegetable soybean, since the crosses are made between tropical and temperate types, a two-pronged approach will be used for the same cross to select both grain and vegetable types in the future. To facilitate such efforts shuttle breeding will be employed between AVRDC and the collaborating national programs or the AVRDC Regional Program in Asia (Thailand).

Seed production technology and seed quality research need to be strengthened since these are serious problems in the tropics.

References

Anon. 1987. Annual Report of Dryland Food Crop Improvement Series. Department of Agriculture and Forestry. Taiwan Provincial Government, 104–107.

AVRDC. 1991. 1990 Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan, 84–87.

Bravo, J.A., Fehr, W.R., and Rodriguez de Cianzio, S. 1980. Use of pod width for indirect selection of seed weight in soybeans. Crop Science, 20, 507–509.

Cheng, Y.W., and Chan, K.L. 1965. A monograph of introduced soybean varieties in Taiwan. Taiwan Agricultural Research Institute. Taipei, 244 p.

Fehr, W.R., Caviness, C.C., Burmood, D.T., and Pennington, J.S. 1971. Stages of development descriptions for soybeans, *Glycine max* (L.) Merrill. Crop Science, 11, 929–931.

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

Shanmugasundaram, S. 1979. Varietal development and germplasm utilization in soybean. Tech. Bull. No. 13. Asian Vegetable Research and Development Center, Shanhua, Taiwan. 36 p.

Shanmugasundaram, S., Chen, Li Fen, and Yan, Miao-Rong. 1990. Research on vegetable soybeans. *In*: Proceedings of International Conference for Soybean Processing. Gongzhuling, Jilin Province, China (in press).

Shanmugasundaram, S., Tsou, S.C.S., and Cheng, S.H. 1989. Vegetable soybeans in the East. In: Pascale, A.J. (ed.) World Soybean Research Conference IV. Buenos Aires, Argentina, 1979–1986.

Shinohara, S. 1989. Vegetable seed production technology of Japan, vol. II. Tsukuba International Agricultural Training Center. Japan International Cooperation Agency, Tokyo, 200–204.

Sirikul, W., Srinives, P., and Shanmugasundaram, S. 1990. Primary leaf size as a selection criterion for vegetable soybean. Thai Journal of Agricultural Science (in press).

Vegetable Soybean Seed Production Technologies in Japan

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Abstract

In Japan, most vegetable soybean seeds are produced and sold by private seed companies. Each company has its own techniques for producing seeds, but techniques are generally similar. One example of seed production in Iwate Prefecture is discussed. Iwate Prefecture is situated in Northern Japan. The average yearly temperature is 10°C, and during the soybean growing period, the accumulated temperature is 1500-2000°C.

Seed Production and Supply System

The Iwate Prefectural Agricultural Experiment Station is concerned with breeding pure lines, plus breeders' and foundation stocks. The Iwate Seeding and Plant Center works on the multiplication of seeds. This Center was established and maintained by the agricultural groups and the prefecture, and has a propagation farm situated in a disease- and pest-free area. They produce and supply good usable seed to the farmers. The Center works closely with the Agricultural Experiment Station, and predicts the future use of seeds, and plans accordingly.

Breeding

Many seed companies deal mainly with the kinds of seeds that can be marketed between June and August, the vegetable soybean season. They are trying to produce plants that mature early and larger and greener pods with good appearance. Iwate Prefecture also has the same goals, and aims to develop plants that are resistant to mosaic and fusarium blight and do not lodge easily. Different types of plants for taste and ease of transplanting are also being developed.

One of the factors in evaluating seeds for market is the length of time they can be kept for sale. It is desirable to extend this period as much as possible. Therefore Iwate Prefecture produces 11 types of soybean seeds that range from early-maturing types to late-maturing types. Five of these were bred and produced in the Iwate Prefectural Agricultural Experiment Station. The breeding methods used were mainly hybridization and selection and radiation, using local varieties and seeds that are already marketed.

Cultivation Methods

To avoid problems such as the soybean cyst nematode, the land formerly used for pulse crops such as soybean and adzuki bean should not be used. Also plants of different varieties that produce flowers at the same time should not be planted close by. Land is chosen where the soil fertility is evenly distributed and easy to control. Before plowing, the soil is assessed and when necessary improved. The ideal soil pH is 6.0-6.5, and for every 100 g of dry soil there should be 10 mg of available phosphorus. Compost should be applied at a rate of 1-15 t/0.1 ha. The rate of fertilizer application is: N=3-4, P=15, K=8-10 kg/0.1 ha. In producing seeds, the application of nitrogen fertilizer is usually one-half to one-third the amount of ordinary usage in soil.

The seed planting time usually follows the local times, however, seeds that germinate easily, and those that crack open their pods easily, should be planted about 20 days after the usual seeding times. Plants that have an instability in emerging from the soil also are planted late.

The space between rows is around 70 cm, and the intrarow spacing for early-maturing seeds is 10 cm, and for late-maturing seeds, 20 cm. The emerging plants are protected from bird damage by the use of netting put over the plants. When a seed fails to germinate, seeds are replanted to ensure proper plant stand.

Weeds are controlled by using herbicides and intertillage. The use of herbicides must be followed according to prefectural standards. Herbicides are chosen from 11 kinds, according to the types of weeds that are present, and their usage is carried out to complete the treatment for soil and foliage. The intertillage starts 40 days after seeding, and the ridging up is done 2 or 3 times during the growing period. In Iwate Prefecture, plant protection against disease damage is undertaken for diseases such as purple speck, mosaic, soybean stunt, stem rot, and downy mildew. Concerning insect injury, plant protection is undertaken against soybean aphids, soybean pod borers, and others. We are also concerned about infectious seed-borne diseases.

Each plant is checked at specific growth stages; for example, when the primary leaves unfold, at the flowering stage, and when the plant reaches maturity. Strange plants that emerge are immediately removed. During each of these growth stages, the color of the hypocotyl, shape of leaves, color of flowers, color of the trichome, plant type, pod and seed coat color, the color of the hilum and ecotype are all examined.

Around 7 days after maturity, the seeds are harvested using the bean harvester. The moisture content of the beans must be 16-18% after rack- or stack-drying in a greenhouse. The beans are threshed with a bean thresher and the moisture content further reduced to less than 15% using a ventilating dryer.

After the drying process, the beans are winnowed and separated by screens to sieve out beans of the same size. Damaged beans are discarded. They are given a germination test, and after they meet all the standards, they are marketed.

Future Developments

Vegetable soybeans in general are inferior to grain soybeans in their resistance to disease and other damage. A strong disease-resistant variety must be developed to produce stability of seeds, and to reduce costs of production.

Vegetable Soybean Seed Production Technology in Taiwan

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Abstract

Vegetable soybean is an important export crop in Taiwan. About 95% of the domestic production is exported to Japan. The annual demand for vegetable soybean seed is about 1500 t. In the past, most of the seed was either imported by the frozen food factory or multiplied by the broker. The seeds were impure and the germination was poor. To produce good quality seeds and maintain the germination, the following factors need to be considered: (1) the dry and cool fall season in southern Taiwan is better for seed production than either spring or summer seasons; (2) proper season, location and date of planting need to be chosen; (3) from sowing to harvest best crop management practices should be followed; (4) seeds should be threshed at 18-20% moisture and the cylinder speed of the threshing machine should be adjusted to 10-11 m/sec to obtain good quality seeds; (5) seeds should be carefully dried to below 10% moisture content and should be stored in a cool, dry environment to have satisfactory germination; (6) the seeds should be treated with fungicide prior to sowing.

Introduction

Vegetable soybean is harvested between R_6 and R_7 growth stages when the pods are still green. The vegetable soybean area, production and the demand for seed from 1983 to 1989 are given in Table 1.

Table 1. Pod production and seed demand of vegetable soybean in recent years in Taiwan.

Year	Cultivation area[*] (ha)	Pod production[*] (t)	Seed demand[**] (t)
1983	5012	28, 221	752
1984	6856	37,201	1028
1985	6663	38,550	999
1986	7661	45,677	1149
1987	9813	61,482	1472
1988	10,715	61,455	1067
1989	9607	54,392	1441

[*]Data from Taiwan Agricultural Yearbook.
[**]At 150 kg/ha.

In the vegetable soybean production chain, farmers, intermediaries or brokers and the frozen food factory are involved. The broker usually provides the seeds to the farmer. In the past vegetable soybean varieties Tzurunoko (205) and Ryokkoh (305) were the major varieties grown by the farmers. The purity and germination quality of the seeds of the above varieties were invariably poor. In 1987 Kaohsiung DAIS in cooperation with AVRDC proposed and released the first vegetable soybean variety, Kaohsiung No. 1 (KS No. 1). KS No. 1 is now very popular in Taiwan. The sources of seed for vegetable soybean are: (1) direct import from a Japanese seed company, (2) harvested and saved directly from the vegetable soybean field after full maturity, and (3) seeds produced by the individual farmers. There is a need to organize a systematic seed production strategy to maintain both quality and germination potential. Characteristics of good quality seed include: (1) varietal purity (Belouche and Rodda 1976; Scott and Aldrich 1970); (2) free from other contaminants; and (3) high germination rate (>85%). To meet the above criteria the field management, harvesting, threshing and preparation for storage should all be done carefully.

Effect of Season and Area on Quality

Seasonal differences influence seed quality. Seeds produced from spring, summer and autumn seasons in Taiwan were compared. Poorly filled, damaged and disease- and insect-affected pods in the spring season was 13%, and that of summer and fall crops, 6 and 4%, respectively. Varieties with large seed size such as Tzurunoko and KS No. 1 harvested in the spring season have a lower germination percentage than those harvested in the fall season. The results of seed germination after storage of seeds harvested from different seasons were different. For example, the germination of seeds harvested from the spring season decreased rapidly after 5 months in storage under ambient room temperature, whereas the seed harvested from the fall season maintained over 85% germination even after 1 year storage under the same conditions. The location and crop season characterized by the differences in environmental characters influence the seed weight and germination rate (Table 2).

Table 2. Influence of the seed weight, germination rate and seedling vigor by crop season and cultivation area (Tseng et al. 1987).

Location	Crop season	100-seed wt. (g)	Germination rate (%)
Taipei	1986 Fall	32.0	98
	1896 Spring	33.7	28
Pingtung	1986 Fall	31.4	100
	1987 Spring	34.0	56

*1986 Fall seeds stored 12 months
1987 Spring seeds stored 5 months

Seed Size, Vigor and Growth Relationships

Seed size depends on the genotype of the variety. However, depending upon location and season, the seed size of Tzurunoko and Ryokkoh showed greatest seed size variation (Fig. 1). The results of an experiment with different seed sizes within a variety showed that small seeds had better germination than larger seeds (Tables 3 and 4). Smaller seed size within the variety does not unduly influence the pod yield or pod size and therefore small size seeds of Tzurunoko and Ryokkoh may be advantageous especially under flooding conditions (Chang and Lai 1981).

Under simulated weathering conditions Horlings et al. (1991a) found that germination was negatively correlated with 100-seed weight. Seed quality of small-seeded types was superior to the large-seeded types when harvested and tested in reproductive growth stages R_7, $R_{7.5}$ and R_8. A simulated weathering treatment using a sprinkler may provide a better balance between the biotic and abiotic factors affecting seed quality (Horlings et al. 1991b).

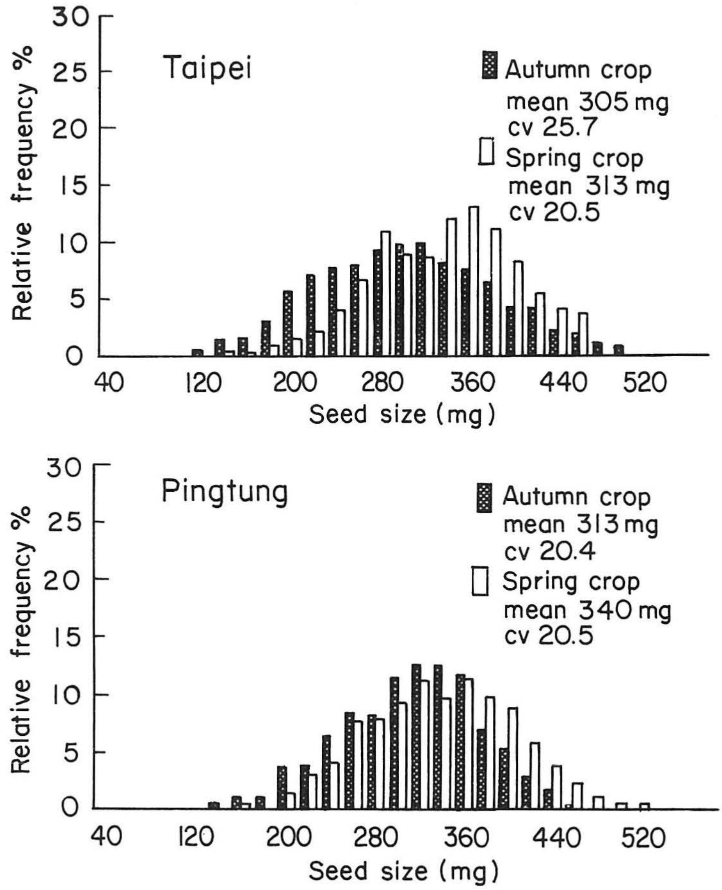

Fig. 1. Relative frequency of seed size of Tzurunoko.

Table 3. Effect of 6 months storage on seed germination rate (%) for seeds harvested in different crop seasons.

Seed classified	1986 Summer		1986 Fall		1987 Spring	
	Room sand	Field	Room sand	Field	Room sand	Field
Extra large	91.6	58.3	98.6	83.0	41.6	34.3
Large	89.6	68.6	97.6	89.0	49.6	41.6
Medium	86.0	57.6	99.6	80.6	66.7	43.3
Small	92.3	62.0	96.0	86.6	65.3	47.0

Management Practices

To produce highest quality vegetable soybean seed, as mentioned earlier, the best season should be chosen. Fall season in southern Taiwan is most suitable. The optimum pH is around 6.0–6.5, and irrigation facilities should be available to avoid moisture stress during the production period. The best planting dates vary with location. For fall season the planting date in Tainan is September and for Kaohsiung it is October (Fig. 2). The seeds for planting should be of good quality with more than 85% germination. A seed rate of about 110–150 kg/ha is recommended.

Table 4. Effect of seed size on germination (Hsieh and Chen 1982).

Grain weight (mg)	Germination rate (%)
200	85
220	95
240	92
260	88
280	86
300	92
320	92
340	89
360	94
380	99
400	93
420	88

The field should be well prepared. The seeds should be treated with fungicides such as Captan, Arasan or Ceresan 75% WP at the rate of 3 g a.i./kg of seed. Treat the seeds with Rhizobium inoculum if the area planted was not grown to legumes in the past. In planting the seeds the distance between rows is about 30–50 cm and the spacing within the row is 5–10 cm and two seeds are planted per hill. The depth of planting is about 2–3 cm.

Fertilizer application should be based on soil tests. The recommended fertilizer application for vegetable soybean is about 10 t compost/ha, 60 kg N/ha, 30 kg P/ha, 50 kg K/ha. At the time of R_2 and at R_5 growth stages it is better to apply 10 kg N/ha. The field should be irrigated after every side dressing.

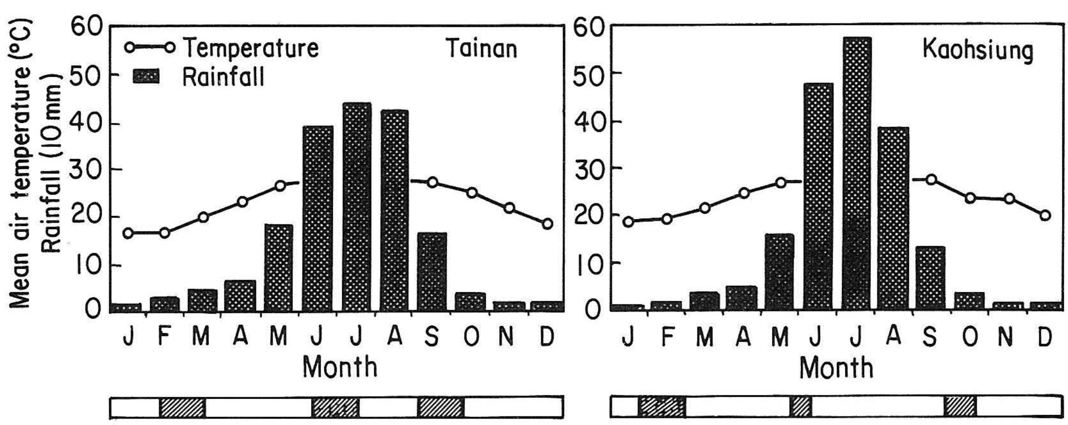

Fig. 2. Vegetable soybean planting periods in Taiwan.

First irrigation is given at 6 days after planting and thereafter once every 15–20 days. Irrigation is suggested depending upon rainfall and soil properties.

Proper control of weeds, insects and diseases should be undertaken to avoid damage due to those pests that will reduce the quality of the seeds produced. Harvesting should be done when the seed moisture content is about 20%. Thresh the plants with a cylinder speed of 10–11 rpm.

The seeds should be dried at 30–35°C for 24–48 hours. The moisture content should be brought down to about 9–10%.

The seeds should have ≥ 98% varietal purity. The seeds of other species < 0.2%; inert matter should be < 2%; germination rate should be > 85%. The seeds can be stored in 0.03 mm thickness polyethylene bags and stored in a cool dry place.

Seed Moisture and Threshing on Seed Quality

Moisture content of seed at harvest is an important factor influencing seed quality. Threshing will be difficult when the moisture content is higher than 25%. But when the moisture content decreases below 20% the seed coat may crack and the seeds may split (Fig. 3). Both the cylinder speed of the threshing machine and the moisture content of the seed are major factors for seed injury during threshing. Generally high cylinder speed and moisture content below 12% causes serious injury to the seed. The results of experiments indicated that 20% seed moisture content and 11 rpm cylinder speed caused minimum seed injury (0.23% breakage); at 14 and 17 rpm, breakage was 4.47 and 6.17%, respectively.

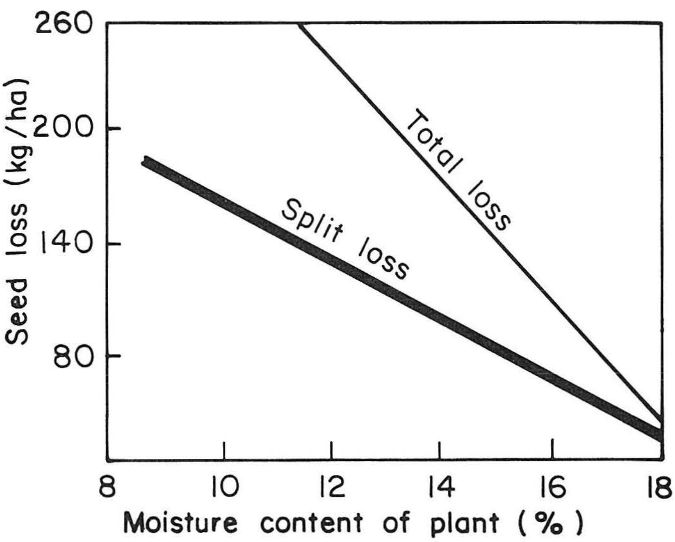

Fig. 3. Effect of moisture content on harvest seed loss.

Influence of Seed Storage on Seed Quality

A number of factors such as storage temperature, humidity, storage container and moisture content of the seed influence the seed quality.

Seed Moisture Content and Storage Duration

Holman and Carter (1952) studied the effect of seed moisture content on storage duration and seed quality. They stored the seeds at 25°C and 65% relative humidity. The results indicated that seeds with 10–11% moisture content did not alter either the germination rate or seed vigor after 1 year in storage. However, the seeds with 11–12% moisture content could be stored only for 6 months without affecting germination. If the seed moisture content exceeds 13%, seed quality is negatively influenced. It was therefore concluded that 10% seed moisture content will maintain the seed vigor and germination rate for 1 year at 25°C and 65% relative humidity (Thomas 1979). At AVRDC the results of trials conducted revealed that an 8–10% seed moisture content and the seeds stored in air-tight tin containers or high density plastic bags and hermetically sealed could maintain high seed viability for 2 years at 30°C if the seed lot had high initial seed viability (AVRDC 1990).

Effect of Container on Moisture During Storage

Variation in moisture content of seed during storage is influenced by packing materials and packing technique. The results showed that seeds with 8.9% initial moisture content stored in sealed metal containers retained the initial moisture content while in other types of storage containers the moisture content of the seed increased after 3 months in storage (Fig. 4).

Effect of Temperature

Seeds stored at 3°C for 9 months had a germination rate of more than 85%. But for the seeds stored at 25°C or room temperature for 6 months the germination rate dropped to 50%. It was concluded that low temperature storage could maintain high seed vigor for longer periods (Table 5).

Table 5. Effect of temperature on seed germination rate (%) during storage period.

Storage condition and variety	Storage period (months)							
	0		12		18		24	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
0°C								
KS. 8	98.5	100.0	96.3	100.0	95.2	98.2	94.8	97.6
Palmetto	99.2	100.0	98.5	99.5	97.0	100.0	96.5	99.0
10°C								
KS. 8	97.6	100.0	97.4	99.3	96.2	96.8	95.0	98.0
Palmetto	99.5	100.0	99.0	99.6	98.4	100.0	97.0	98.5
20°C								
KS. 8	98.3	100.0	92.4	98.4	92.6	95.4	86.2	94.8
Palmetto	100.0	100.0	97.8	99.5	94.5	98.0	94.0	96.4
Sealed metal can								
KS. 8	98.4	100.0	32.0	49.0	0	34.8	0	0
Palmetto	98.6	100.0	48.2	58.6	24.6	49.6	0	36.4
Jute bags (ck)								
KS. 8	98.0	100.0	94.5	96.6	0	0	0	0
Palmetto	98.5	100.0	95.2	98.2	0	0	0	0

Seed Preparation Prior to Storage and Seed Quality

The main objective in treating the seed by physical, chemical or physiological methods prior to storage is to protect the seed, retain its germination rate and decrease damage due to unfavorable environment. Saha and Basu (1981) indicated that hydration-dehydration method could be used for retaining the seed vigor of soybeans during storage. Woodstock and Taylorson (1981) applied polyethylene glycol (PEG 6000) to soybean seed to protect the seeds from flooding injury. Flooding injury during seed germination could be minimized by subjecting the seeds to moisture absorption for 24 hours at 100% RH followed by 1 hour imbibition and air drying prior to storage. Such treatment promotes seed activity and decreases seed deterioration (Saha and Vasu 1981).

Treating the seeds with fungicides, such as captan or carboxin, could prevent the seeds from rotting due to flooding (Chang and Lai 1981; Hsieh and Chen 1982; Grable and Danielson 1965; Minton and Green 1980). However, seeds treated with such fungicides or other chemicals and stored may have reduced seed vigor, and therefore caution should be exercised in storing the seeds treated with chemicals.

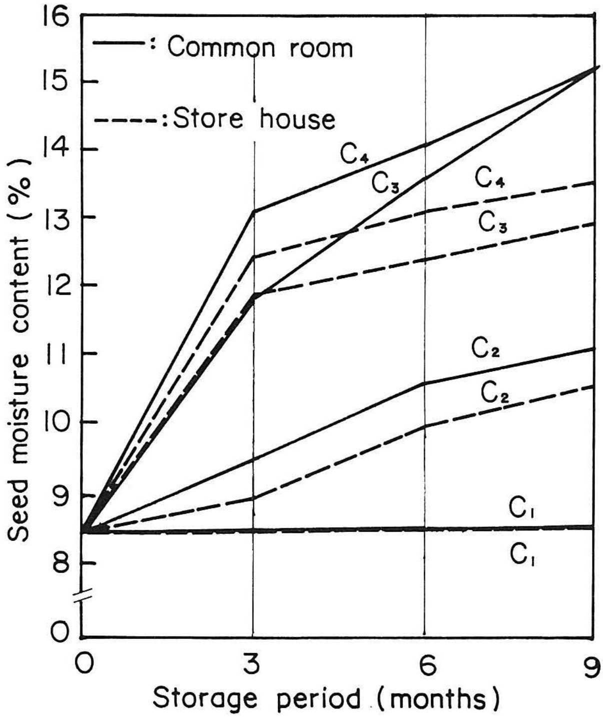

Fig. 4. Effect of storage container on seed moisture content changes.
C_1 = sealed metal container,
C_2 = sealed metal with plastic bag,
C_3= jute bag with plastic bag,
C_4 = cotton bag.

Conclusions

The objective in vegetable soybean seed production is to produce a good quality seed with purity and good germination. It is necessary to pay attention to all the fine details of crop management to produce good quality seed. An understanding of the growing environment, varietal characteristics and its requirements will be helpful in good quality seed production. With large seed size and higher oil content, vegetable soybean seeds are more difficult to produce and storage of them requires better conditions than grain soybean. There are many unknowns in vegetable soybean seed production and storage which need to be studied.

References

Belouche, J.C., and Rodda, E.D. 1976. *In*: Expanding the Use of Soybean. Goodman, R.M. (ed.) Illinois, USA: INTSOY, 38–39.

Grable, A.R., and Danielson, R.E. 1965. Effect of carbon dioxide, oxygen and soil moisture suction on germination of corn and soybean. Soil Sci. Amer. Proc., 29, 12–18.

Holman, L.E., and Carter, D.G. 1952. Soybean storage in farm-type bins. Ill. Agr. Expt. Sta. Bull, 553.

Horlings, G.P., Gamble, E.E., and Shanmugasundaram, S. 1991a. The influence of seed size and seed coat characteristics on seed quality of soybean in the tropics. II. Simulated weathering. Seed Science and Technology (submitted).

1991b. Field weathering of soybean [*Glycine max* (L.) Merr.] in the tropics, as affected by seed characteristics and reproductive development. Tropical Agriculture (submitted).

Minton, E.B., and Green, J.A. 1980. Germination and stand with cotton seed treatment fungicides formulation and rate. Crop Sci., 20, 5–7.

Ravalo, E.J., Rodda, E.D., Tenne, F.D., and Sinclair, F.B. 1980. Soybean seed storage under controlled and ambient condition in tropical environment. *In*: World Soybean Research Conference II, 519–532.

Saha, R., and Basu, R.N. 1981. Maintenance of soybean seed viability by hydration-dehydration treatment. Univ. Coll. of Agri., West Bengal, India, India Agri., 25, 275–278.

Scott, W.D., and Aldrich, S.R. 1970. Modern soybean production. Public. Champaign, Illinois, USA.

Thomas, W. 1979. Seed viability in relation to storage condition in varieties of soybean. Thesis of Univ. of Agri. Sci., India.

Woodstock, L.W., and Taylorson, R.B. 1981. Soaking injury and its reversal with polyethylene glycol in relation to respiratory metabolism in high and low vigor soybean seed. Physio. Plan., 53, 263–266.

Cultural Practices and Cropping Systems for Vegetable Soybean in Japan

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Abstract

Many cropping systems or patterns for vegetable soybeans have evolved as a result of diverse climatic conditions and cultivars, as well as the use of facilities. Since early-maturing cultivars, which are used for forcing and early harvest type of cropping, tend to be rated low in taste, we need to breed early-maturing cultivars with good taste quality. Cultural practices such as fertilization, irrigation, and control of weeds, insects and diseases are common to vegetable soybean culture and matured soybean culture. Cultivars that have both high resistance to major diseases and good taste have not yet been improved, so that the control of the diseases greatly depends on chemicals. Since the time required for harvest is so long and labor-intensive, more efficient depodding machines need to be developed. Further research is also needed to provide more rational ways of rotating vegetable soybeans with other crops, leading to low-input production.

Introduction

Cultural practices for producing vegetable soybeans are, in principle, the same as those for production of matured grain soybean. In the normal season cropping that is conducted outdoors, there is no significant difference in cultural practices. For vegetable soybeans, however, special attention is necessary in adopting cultivars and cultural practices, since some specific characters such as fresh green color, more seeds per pod, etc., are required. The control of temperature is also necessary in forcing culture in which glasshouses or vinyl houses are used. This paper summarizes the present status and future research needs on cultural practices and cropping systems for vegetable soybeans in Japan.

Cultural Practices

Cropping Patterns and Cultivars

Classification of cropping patterns. The Japanese archipelago stretches from 20 to 46° north latitude, resulting in great variations in climate. These diverse climatic conditions, combined with cultivar earliness and the use of facilities or materials for retaining warmth, allow many cropping patterns, as shown in Fig. 1.

Normal season pattern of cropping is most commonly adopted in every production area. In this cropping pattern, soybeans are grown under the natural climate condition of each area. Cropping season varies with area, depending on its climate conditions. For example, seeding is conducted around May and harvest is around August in Hokkaido, whereas March-May for seeding and June-August for harvest are common in Kyushu. In this cropping pattern, numerous cultivars including native ones are used. This cropping pattern results in lower production costs than the others, but the price of the product is lowest because the supply is high at this time of year.

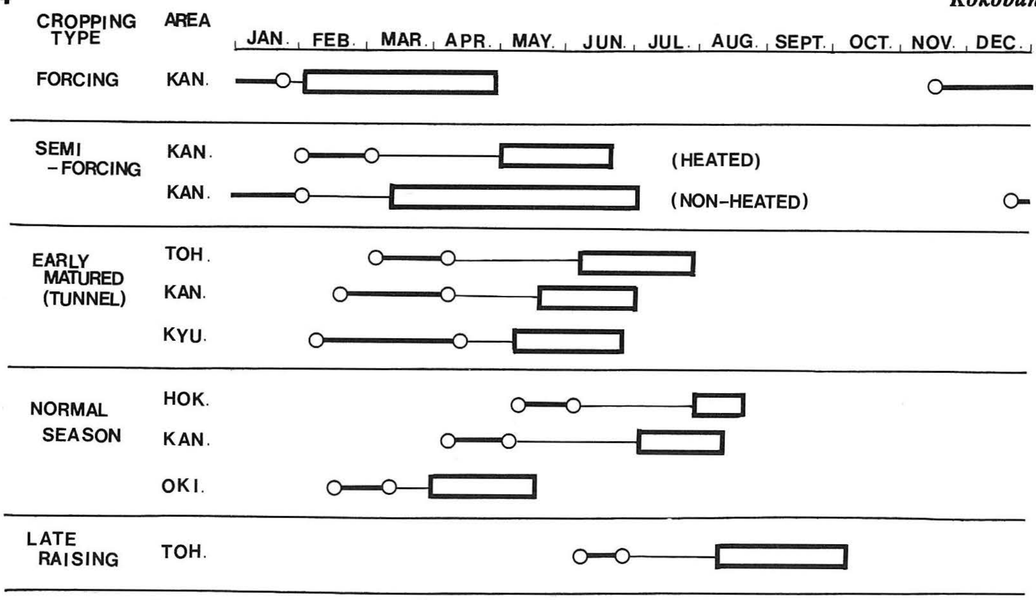

Fig. 1. Cropping patterns of vegetable soybean in Japan.
Hok. Hokkaido, Toh.: Tohoku, Kan.: Kanto — Chugoku, Kyu.: Kyushu, Oki.: Okinawa
O——O period of sowing, ▭ period of harvest.
Adapted from Natl. Res. Inst. Veg. Ornam. & Tea (1989).

Forcing culture is carried out to harvest vegetable soybeans around February-April because the price is highest at that time of year. Heated glasshouses or vinyl houses are necessary, so that it is the most costly type of culture. This cropping pattern is restricted to warmer areas and demand for the product is limited. Semiforcing culture aims to harvest at the period just after the harvest by forcing culture, using glasshouses or vinyl houses, which are heated in many cases.

Early maturity culture is conducted in most production areas, aimed at harvesting before normal season products appear on the market. Like normal season cropping, this pattern of culture is widespread, from Hokkaido to Kyushu. In this pattern, an unheated vinyl tunnel is commonly used to promote early growth of plants. Although this pattern of cropping is a little more costly than normal season cropping, it is adopted by many farmers because demand is great and the price is relatively high. In addition, ending the cropping in early summer enables the farmer to grow autumn vegetables such as radish or Chinese cabbage, even in the cooler regions.

Late maturity allows harvesting in September and October when normal season production is completed. Late maturing cultivars are used in cold and cool regions. Some of the products are transported to large cities, and some of them are processed for freezing.

In all the cropping patterns, mulching with vinyl film is commonly used, since film mulching promotes early gro\,th of soybeans, as reported by many workers (e.g. Moichi et al. 1983). The effects were more positive in early-maturing cultivars than in late-maturing cultivars. Growth tended to be excessive by mulching the late-maturing cultivars (Iwase et al. 1983). The major effect of vinyl film mulching was to increase soil temperature, resulting in promoting phosphorus absorption by roots (Matsumura 1986). A comparison of three kinds of polyethylene film mulching showed that silver-colored film increased the growth and yield more than black or transparent film (Matsui et al. 1981).

Cultivars adaptable to each cropping pattern. Specific cultivars must be selected for each cropping pattern. Soybean cultivars can be classified into three groups: summer, autumn or intermediate, from their response to temperature and daylength (Matsumoto 1942). A summer type of cultivar is sown in spring and harvested in summer. Its growth is sensitive to temperature but not to daylength. This type of cultivar is adaptable to forcing, semiforcing and early maturity pattern of cropping. In contrast autumn type is sown in summer and harvested in autumn. Its growth stage, especially flowering and maturity, is greatly accelerated by short days. This type is appropriate to late cropping. Intermediate types of cultivars are mainly used for normal season culture. Typical combinations of cropping types and cultivars are shown in Table 1. Generally, cultivars that mature early are evaluated low in terms of taste. It is therefore necessary to breed early-maturing cultivars with good taste, and which have also adaptability to forcing and early maturity cropping.

Table 1. Major cultivars used for each cropping pattern of vegetable soybean in Japan.

Cropping type	Earliness of cultivars	Days from sowing to harvest	Cultivars
Forcing and semiforcing	Very early	75–80	Okubarawase, Hakuchou, Gokuwaseozaya
	Early	80–85	Sapporomidori, Yukimusume, Hakuchou, Wasemidori
Early maturity	Very early	75–80	Okubarawase, Hakuchou, Gokuwaseozaya
	Early	80–85	Sapporomidori, Yukimusume, Tamasudare
Normal season	Early	80–85	Hakuchou, Sapporomidori, Waseshiroge
	Medium	95–100	Mikawajima, Shiratsuyu
Late cropping	Medium	105–	Kegon, Tsurunoko

Adapted from Kohno (1989).

Raising of Seedlings

In forcing, semiforcing and early maturity culture, raised seedlings are transplanted in many cases, to ensure rapid and uniform plant growth. Transplanting of raised seedlings is sometimes conducted in normal season and late cropping as well, so as to avoid missing hills and bird attack on young seedlings.

Ways to raise seedlings. Depending on the type of soil container, seedlings can be raised as follows: soil bed raising, box raising and pot raising.

In soil bed raising, seeds are sown directly on soil in a glasshouse or vinyl tunnel. Soil bed is prepared either without fertilizer application, or with the application of superphosphate in phosphate-deficient soil such as volcanic ash soil. Seeds are sown about 4×2 cm apart, then covered with about 1 cm of soil. After being watered, the bed is often covered with vinyl film to maintain warmth and moisture.

In box raising, nursery boxes that are designed for the raising of rice seedlings are used as soil container. These containers are easy to handle and carry to the field where the raised seedlings are to be transplanted.

Since soybeans are not highly tolerant to transplanting, special care is needed not to damage the root. To minimize damage, paper or plastic pots are used as soil container. The seedlings grown in these pots tend to grow faster after transplanting. These pots were originally designed for raising lettuce or beet.

Characteristics of transplanted seedlings. Transplanting is normally conducted 15–20 days after emergence, when seedlings reach primary leaf expansion stage. In forcing culture, seedlings are transplanted twice in some cases, first to pots, then to field (Sawachi 1971). Transplanted plants differ morphologically from directly sown plants (Fig. 2). The top weight and stem length are suppressed by transplanting, and the extent of the suppression is greater as the plants are transplanted later. But the ratio of pods to total weight tends to be greater in transplanted plants. The short-stemmed and dense-podded shape of transplanted plants is desirable when selling vegetable soybeans with the stem.

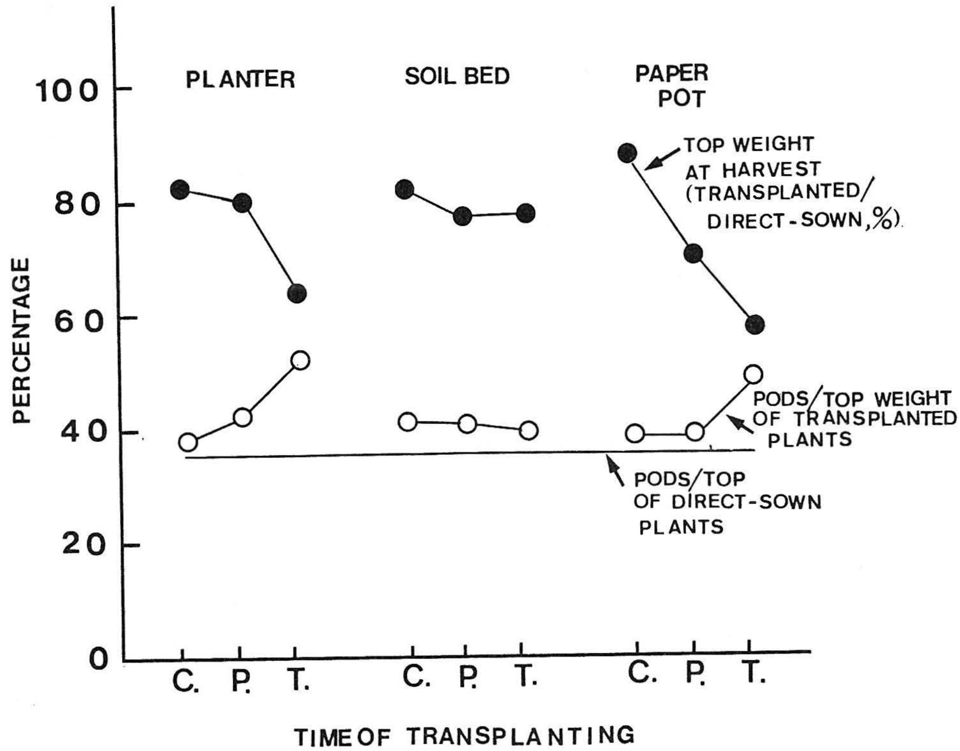

Fig. 2. Effects of seedling raising and time of transplanting on the top growth (upper) and pods/top ratio (lower). Seedlings were raised in three ways (sown on planters, soil bed or paper pot), then transplanted at three growth stages (C: cotyledons expanding, P: primary leaves expanding, T: first trifoliolate leaves expanding). Adapted from Kohno (1989).

Early-maturing cultivars, when they are transplanted, are apt to bear fewer pods because of poor growth. As a countermeasure to the poor growth, long day treatment during seedling raising increased its growth after transplanting, resulting in yield increase as well (Suzuki et al. 1985; Suzuki and Yashiki 1990). But this treatment is not commonly used. Transplanting is labor-intensive and limits production, as does harvesting. The use of transplanting machines, which were developed for other kinds of crops such as tobacco, can be labor-saving (Kato et al. 1981). Further research is needed to modify the machines, since they were not efficient enough to achieve a desirable planting density and planting depth.

Planting, Fertilizing, Irrigation and Temperature Control

Planting density. The optimum planting density primarily depends upon cultivar used and planting time. The density ranges from 20 to 30 for forcing culture in the glasshouse to 5–10 plants/m^2 for normal season culture in the field. Higher density can increase soybean yield, but might cause longer stems which could result in lower prices, when sold as a form of pod-bearing stem.

Fertilization. Fertilization for vegetable soybean is in principle the same as that for matured grain soybean. In forcing or early maturity culture, however, a larger amount of nitrogen is usually applied, aiming to promote early growth of plants. The standard rates of N, P, K and lime are 40-100, 80-100, 80-120 and 1000 kg/ha, respectively. When residual effects of the preceding crop are expected, there is a need to reduce the amount applied. When early growth of plants is inadequate, top dressing of nitrogen during growth is effective.

Irrigation. Soybean plants require a large amount of water for growth. Insufficient water, particularly during flowering to pod growth stages, induces flowers and pods to drop. Therefore irrigation is essential when soil moisture is low during the critical stages. Since excessive soil moisture gives an adverse effect on root activity, special care must be taken not to flood the plants.

Control of temperature. In the culture using a glasshouse or vinyl tunnel, temperature control within the house or tunnel affects stem length and podding. Although there are few studies on temperature control in vegetable soybean culture, it is recommended (Kohno 1989, Sawachi 1971) to keep the temperature less than 25–30°C during the day and more than 10–15°C at night.

Control of Weeds, Insects and Diseases

Control of weeds. In the glasshouse or field where crops are grown successively, weeds are not a major obstacle. However in the paddy fields where production of soybeans has recently increased in Japan, overgrowing weeds often obstruct the growth of soybeans. The control of the weeds greatly depends on herbicide applications, particularly in the larger fields. Since herbicides designed to be used specifically for vegetable soybeans have not been developed, those for matured soybeans are being used. Three systems of weed control in soybean fields, which consist of the soil and foliar applications of herbicides in combination with tillage and picking-off by hand, are shown in Table 2. With the first and second sequences, soil treatment by herbicides comes just after seeding. After emergence, foliar application of herbicides, intertillage and picking off by hand keep the field weed-free. The second method omits foliar treatment of herbicides. The third system is adopted when soybeans are sown without tillage just after wheat or barley, where weeds can survive after the harvest of preceding crops. To control these weeds the foliar type of herbicides are sprayed before seeding of soybeans. After emergence, foliar types of herbicides are applied, then followed by picking off by hand, if necessary.

Table 2. Weed control systems used for vegetable soybean in Japan.

Tillage--->	Seeding------>	Emergence------------> Maturity
Rotary —	— St. —	— Ft. It. Po. —
Rotary —	— St. —	— — It. Po. — —
Non Ft. —	— St. —	— — Ft. Po. — —

St.: Soil treatment of herbicide, Ft.: Foliar treatment of herbicide, It.: Intertillage, Po.: Picking weed off by hand. Adapted from Noguchi (1990)

For all three sequences, the herbicides commonly used are: trifluralin, alachlor, metolachlor, benthiocarb-prometryne, linuron and prometryne for soil application; alloxidim, sethoxydim and fluazifop for postemergence foliar application; and glyfosinate for pre-seeding foliar application to preceding crops.

Control of diseases and insects. Damage caused by diseases and insects occurs commonly in the culture of either vegetable soybean or matured soybean. General control measures are therefore common to the two cultures. Cultural practices and chemical measures to control a few major diseases that cause severe damage to soybean are given in Table 3. Besides these diseases, root necrosis (*Calonectria crotalariae*) and *Phytophthora megasperma* which damage the roots and stems of plants are very destructive diseases. As shown in Table 3, since cultivars resistant to soybean mosaic virus, purple seed stain, etc., are presently available, the choice of resistant cultivars in infected areas is the most effective control measure. Unfortunately, however, the bean quality of these resistant cultivars as vegetable soybeans is not highly valued by consumers. Therefore it is necessary to breed new cultivars that have both high resistance to major diseases and high bean quality as vegetable soybeans.

Table 3. Cultural and chemical methods to control major diseases of vegetable soybean in Japan.

Disease	Cultural	Chemical
Soybean mosaic virus	Use of virus-free seeds, Resistant cultivar	Application of insecticide to control aphids
Purple seed stain	Use of virus-free seeds, Resistant cultivar	Application of fungicide at pod-filling stage
Downy mildew	Avoidance of close planting or heavy fertilization	Application of fungicide

Major insects attacking vegetable soybeans in Japan include aphids, soybean pod gall midge, soybean pod borer, a variety of bugs, etc. Cultivars with high resistance to these insects have not yet been developed, nor have any effective cultural practices to control them emerged, so that the application of insecticides is the only practical way to control them.

Harvest

The best time for harvesting vegetable soybeans is when most of the pods become filled and turn fresh green, and the duration of harvest time is short. Delayed harvest leads to the deterioration of bean quality, that is an increase in hardness or a change of color. The time required for harvest occupies most of the working hours devoted to vegetable soybean production. Working hours needed to harvest vegetable soybeans, radish and Chinese cabbage are compared in Table 4. In vegetable soybeans, the time for harvest which includes from harvest to shipping, occupies about 61 and 87% of the total for early maturity culture and normal season culture, respectively. Among the hours for harvest, depodding is the most time-consuming, and it limits the acreage. A few types of depodding machines have been developed and used by large-scale farmers. Their efficiency ranges from 40 to 60 kg/hour. Morita and Takaura (1987) found no significantly bad effect on external appearance of vegetable soybeans when the pods were removed by machine. Since research on the development of the machine has already been conducted, there will soon be further improvements in its efficiency.

Table 4. Working hours for harvest and the other management practices in vegetable soybean production in Japan.

	Working time (hours/ha)		
Crop	Harvest	Other	Total
Vegetable soybean (Early maturity)	1280 (61.0 %)	820	2100
Vegetable soybean (Normal season)	1760 (86.9 %)	265	2025
Radish (Early maturity)	935 (33.4 %)	1865	2800
Chinese cabbage (Normal season)	750 (54.3 %)	630	1380

Early maturity: using vinyl tunnel. Hours for harvest includes all the time from harvest to shipping. Figures in parentheses are percentage of harvest to total. Adapted from Kohno (1989).

Cropping Systems

Crop Rotation Including Vegetable Soybean

In the traditional cropping pattern where vegetable soybeans are grown in normal season, spring vegetables precede and autumn vegetables follow the vegetable soybean in many cases. In the culture using a glasshouse, it is possible for vegetable soybeans to be combined with various kinds of vegetables. Typical combinations of vegetable soybean and other vegetables in cropping sequence are illustrated in Fig. 3. Tomato and cucumber are often grown before or after vegetable soybean in forcing

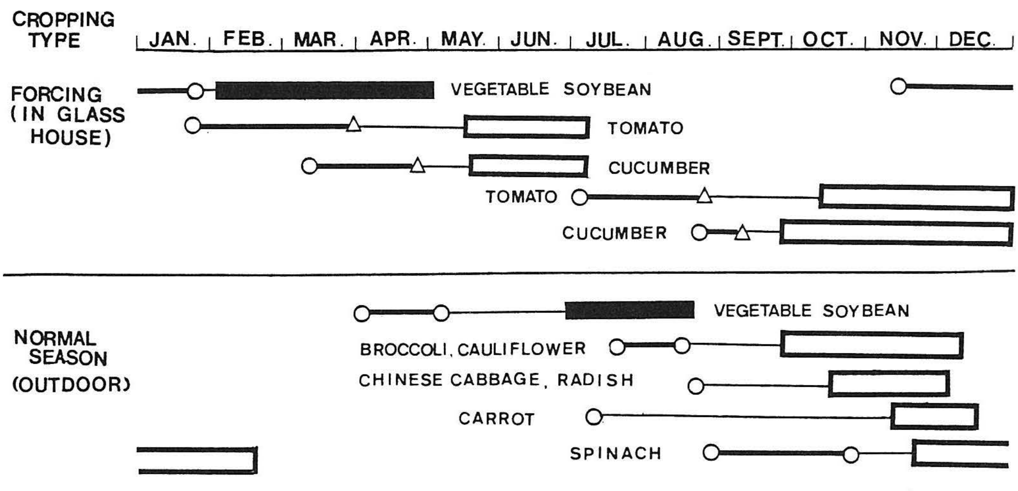

Fig. 3. Cropping sequences including green soybean in Japan.
period of sowing, transplanting, period of harvest.
Adapted from Kohno (1989).

culture. Vegetable soybean of normal season or matured culture is often followed by radish, Chinese cabbage or spinach which can be sown in summer to autumn and harvested before spring. Many studies indicate that to rotate soybeans with other crops,is generally better than growing soybeans continuously (Johnson 1987). The rationale of the yield advantage of the rotation is often obscure. Thus further research is needed to provide more rational ways of rotating vegetable soybeans with other crops for each production area.

Effects of Continuous Cropping

Soybean plants are relatively tolerant to continuous cropping, but it may result in a decrease of yield. There are many reports that the grain yield of vegetable soybeans begins to decrease significantly after 3-4 years of continuous cropping. The results of a survey on the damage caused by continuous cropping of soybeans and measures being taken by farmers in selected soybean-producing areas are given in Table 5. The decreased yield was mainly due to the poor growth caused by an increase in soil-infectious diseases. Chemical controls such as seed disinfection, spraying of pesticides and soil disinfection were the main measures taken by farmers. They expected the scientists to breed cultivars with high resistance to these diseases, and to develop more effective chemicals. However, rotating soybeans with other crops is a more efficient way of avoiding damage caused by continuous cropping while retaining higher yield with less input.

Table 5. Diseases caused by continuous cropping of vegetable soybean and measures being taken by farmers to control them in selected production areas.

Area	Cropping type	Causes	Measures
Niigata	Early maturity, Normal season	Phytophthora rot, poor growth,etc.	Seed disinfection, etc.
Tokyo	Early maturity, Normal season	Bacterial blight, etc.	Chemical spraying
Osaka	Early maturity, Normal season	Root necrosis, etc.	Soil disinfection, etc.

Adapted from Anon. (1984).

References

Anon. Vegetables and Ornamental Crops Research Station. 1984. Kidney bean, broad bean and vegetable soybean. Mis. Pub. Veg. & Ornam. Crops Res. Stn., 18, 36-37.

Iwase, T., Oba, S., Yanagida, M., Tomita, H., Naijyo, M., and Higuchi, K. 1983. Cultural method of vegetable soybean for summer and autumn crop. Tohoku Agric. Res., 33, 239-240.

Johnson, R.R. 1987. Crop management. *In*: Wilcox, J.R. (ed.) Soybeans:improvement, production, and uses (2nd ed.). Madison:ASA,CSA,SSSA, 355-390.

Kato, A., Kudo, M., and Matsuo, K. 1981. Transplanting culture of soybeans (2) — in Tohoku Region. Agr. and Hort., 56, 1495-1498.

Kohno, S. 1989. Vegetable soybean. In: Nobunkyo (ed.) Encyclopedia of olericulture 6. Tokyo: Nobunkyo, 412-429.

Matsui, S., Nakamura, M., Watanabe, E., Ohyabu,T., and Kato,Z. 1981. Effect of mulching on growth and yields of vegetable soybeans. Res. Bull. Fac. Agr. Gifu Univ., 45, 277-288.

Matsumoto, T. 1942. Distribution of soybean cultivars. Breeding Research, 1, 144-149.

Matsumura, S. 1986. The growth stimulation process of soybeans by polyethylene film mulch. Japan. J. Soil Sci. Plant Nutr., 57, 377-383.

Moichi, S., Onodera, H., Ohno, Y., Sasaki, T. 1983. The cultivation for advancement of cropping season for vegetable soybeans in the northern area of Iwate Prefecture. Tohoku Agric. Res., 33, 241-242.

Morita, S., and Takaura, Y. 1987. The effect of machine harvesting on the quality of vegetable soybeans. Bull. Osaka Agr. Res. Cent., 24, 49-54.

National Research Institute of Vegetables, Ornamental Plants and Tea. 1989. Vegetable soybean. Mis. Pub. Natl. Res. Inst. Veg., Ornam. & Tea, 2, 142-147.

Sawachi, N. 1971. Vegetable soybean. *In*:Ienohikarikyokai (ed.) Modern agricultural technology monograph. Tokyo: Ienohikarikyokai, 131-169.

Noguchi, K. 1990. Weeds in upland field and their control in Japan. *In*: Textbook for trainee of JICA. Japan International Cooperation Agency (JICA) Tokyo:JICA,30.

Suzuki, K., Yashiki, T., and Takeuchi, E. 1985. Effects of long day treatment during the period of raising seedling on growth and yields of vegetable soybeans after transplanting. 1. The effects on two stages of seedlings. Bull. Chiba Agric. Exp. Stn., 26, 39-46.

Suzuki, K., and Yashiki, T. 1990. Effects of long day treatment during the period of raising seedling on growth and yields of vegetable soybeans after transplanting. 2. Effect of the length of light period and the starting age of seedling. Bull. Chiba Agric. Exp. Stn., 32, 123-129.

Management Inputs and Mechanical Harvesting of Vegetable Soybean in Taiwan

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Abstract

Vegetable soybean is one of the major horticultural export crops of Taiwan. More than 90% of the planted area is in Pingtung County, where the National Pingtung Institute of Agriculture has undertaken several projects to solve mechanization problems. We developed a zone-tillage pneumatic precision seeding and fertilizing machine, which decreases seed damage and saves on labor. We started our vegetable soybean harvester studies in 1985, and developed a two- and four- row reciprocating mower-type commercial model, which can leave 3-5 kg/bundle on the ground. From the studies of vegetable soybean threshing machines, we learned that the most suitable linear velocity for a feeding chain is 0.72 m/sec, and the optimum angular velocity for a threshing cylider is 400 rpm with an effective diameter of 36 cm. To protect the pods from mechanical injury while threshing, we developed two types of rubber threshing teeth. We also developed a reciprocating vibration-type separating machine to pick out the one-kernel pods. One separator has the capacity to support 10–15 threshers.

Introduction

Currently, vegetable soybean is planted in an area of more than 10,000 ha. The yield is 10,000–12,000 kg/ha. Vegetable soybean requires 700 person-hours/ha for seeding, fertilizing, harvesting, threshing, and separating operations. Therefore, mechanization of vegetable soybean production is very important to decrease production costs and to solve.the serious labor shortage problem in the rural community.

Seeding and Fertilizing Machine

We developed a zone-tillage pneumatic precision seeding and fertilizing machine (Wung and Su 1984). With precision seeding, we were able to decrease the damage to seeds. The WS-2 type fertilizer was one of the best devices for the fertilizing operation (Wung and Su 1981). The zone-tillage device that we developed, and which was accepted by our farmers, uses a small rotary to open a furrow 25 cm wide and 16 cm deep for drainage and irrigation. The soft soil is covered evenly above the seedbed 3–5 cm thick and 50 cm wide on both sides. This soil situation was suitable for bedding (Wung and Su 1984).

Harvesting Machine

We developed a two- and four-row reciprocating mower-type commercial model for harvesting operations, which can leave 3–5 kg/bundle on the ground. The damage rate of the pods was 1.0%, with a field loss less than 4.0%. The 1-m wide four-row harvester can work at 0.6 m/sec operating speed, and needs 7–8 hours/ha.

Threshing Machine

From the studies of vegetable soybean threshing machines, we determined that the most suitable linear velocity for a feeding chain is 0.72 m/sec, and the optimum angular velocity for a threshing cylinder is 400 rpm with an effective diameter of 36 cm. To protect the pods from mechanical injury while threshing, we developed two types of rubber threshing teeth. According to performance tests, damage rate was decreased to 10.5%. It can reach 95% in threshing rate efficiency with a capacity of 60 kg/hour. That is 6–8 times faster than hand threshing.

Separating Machine

The reciprocating, vibration-type separating machine we developed is used to pick out the one-kernel pods. Performance tests show it is suitable in separating variety 205 vegetable soybean pods, and can reach a 900 kg/hour capacity. With the sieve in the horizontal position, and the vibrating frequency at 400 cpm it can reach a 96.3% accuracy rate. One separator has the capacity to support 10–15 threshers.

Materials, Installation and Methods

Materials

The variety we chose in this series of studies was 205 (Tzurunoko) vegetable soybean. The synthesized compound granule-type fertilizers No. 1, 5, and 39 were adopted.

Installations

For the mechanization study of vegetable soybean, the Institute had developed some special devices as follows: (1) a four-row zone-tillage pneumatic precision seeder (Wung and Su 1982; Su and Wung 1988); (2) WS-2 type fertilizer (Wung and Su 1981); (3) two- and four-row reciprocating mower-type harvester (Hsieh and Hsieh 1985); (4) blower test device and a variable speed-type thresher; and (5) separating test device.

Methods

Seeding and fertilizing machine. First, static performance test devices for both seeding and fertilizing operations were established to determine the best conditions. They were then tested in the soil-bin testing stand, and the data were analyzed. Four model fertilizers used in Taiwan recently were also evaluated. Finally, a zone-tillage machine was developed for field-testing.

Harvesting machine. Before designing the harvester, the physical properties of vegetable soybean were analyzed to determine the plant's center of gravity and the distribution of pods on the plants. In Taiwan soybean seeding is done in 4 rows in a 1-m width ridge, so two models were developed for field-testing. Gross field loss was investigated and the primary design was modified.

Threshing machine. For best blower conditions, a blower testing device was used to vary wind velocity and test the accuracy rate of pod separation. During the threshing machine test, the optimum type, clamping point, and velocity of feeding chain to decrease pod injury during the feeding process was studied. In our threshing drum design, the threshing teeth were arranged in 4-, 5-, and 6-thread screw types (Hsieh 1985), and with 3, 4, and 5 cm radial spacing as the optimum teeth arrangement for seeding. To protect the pods from mechanical injury while threshing, two types of rubber threshing teeth, one solid and the other with a keyhole in the center for the threshing drum were developed (Hsieh 1985). Two types of sieves, one flat and one semicircular with a 98° contact angle, were developed to study their effects on the threshing rate.

Separating machine. A reciprocating, vibration-type separating test device was developed to pick out the single-seeded pods. In the test process, the dimensions of one- , two- and three-seeded soybean pods and their static friction angles were analyzed first. With this device it is possible to control the vibrating frequency and the sieve angle from horizontal to 8°. Different percentages of single-seeded pods were mixed for the test.

Results and Discussion

Seeding and fertilizing machine

A zone-tillage pneumatic precision seeding and fertilizing machine was developed. With precision seeding, the damage to seeds could be decreased to realize a substantial saving.

The S-diagram shows that the WS-2 type fertilizer was one of the best devices for the fertilizing operation (Wung and Su 1981).

The zone-tillage device that was accepted by our farmers uses a small rotary to open a furrow 25 cm wide and 16 cm deep for drainage and irrigation. The soft soil is covered evenly above the seedbed 3–5 cm thick and 50 cm wide on both sides. This soil situation was suitable for budding (Wung and Su 1984).

Harvesting machine

Vegetable soybean harvester studies were begun in 1985, and a two- and four-row reciprocating, mower-type commercial harvester that could leave 3–5 kg/bundle on the ground was developed.

The average plant height of variety 205 (Tzurunoko) is 72.25 cm, and its center of gravity is 21.97 cm from the cutting point with a 16–29 cm range (Hsieh and Hsieh 1985). After cutting, the best clamping point of transport chain is within that range, so the left lower chain was designed to clamp the 10 cm point and the upper chain the 25 cm point, and the right clamp chain clamnped the 16 cm point (Hsieh and Hsieh 1985).

In general, the cutting speed of the mower is 1.5 to 2 (Esaki 1977); 1.8 (Hsieh and Hsieh 1985) was selected for this harvester's design, resulting in a 0.9 m/sec mean cutting speed of the shear mechanism, which allowed a walking speed of 0.5 to 1 m/sec (Hsieh and Hsieh 1985).

The average damage rate of the pods was 1.0% (You et al. 1990), with a field loss less than 4.0%. The 1-m wide four-row harvester can work at 0.6 m/sec operating speed and needs 7-8 hours/ha (You et al. 1990).

Threshing machine

According to the blower test, the best wind velocity for dividing variety 205 pods from leaves was 11 m/sec (Tzeng and Hsieh 1988) with its wind guide plate angle at 21°. It can reach a 95.7% accuracy rate in the primary outlet (Tzeng and Hsieh 1988).

From earlier studies , it was known that the most suitable linear velocity for a feeding chain is 0.72 m/sec (Hsieh 1983), and the optimum angular velocity for a threshing cylinder is 400 rpm with an effective diameter of 36 cm (Hsieh 1985).

The rubber threshing tooth with a keyhole in the center was selected to arrange the threshing drum in 6-thread screw and 3 cm space (Hsieh 1985). According to the performance test, this device can decrease damage rate to 10.5% (Hsieh 1985).

The optimum concave sieve for vegetable soybean was a semicircle type with a 98° contact angle. Its threshing rate can reach 94.2%, 13.3% higher than with a flat sieve (Hsieh 1985).

It can reach a 95% threshing rate efficiency and a capacity of 60 kg/hour. This is 6–8 times faster than hand threshing.

Separating machine

Variety 205 vegetable soybean pods with one kernel are 3.31–4.03 cm long, 1.19–1.35 cm wide, and 0.74–0.92 cm thick. For two-kernel pods the ranges are 4.44–5.01 cm long, 1.22–1.38 cm wide, and 0.75–0.93 cm thick, and for three-kernel pods, the range is 5.28–5.96 cm long, 1.24–1.40 cm wide, and 0.80–0.94 cm thick (Shieh and Chen 1987).

The static friction angle of vegetable soybean pods is between 8 and 11° and tends to slide along its longitudinal axis (Shieh and Chen 1987).

If the amount of one-kernel pods, which we hope to pick out, is less than 25% such as variety 205 vegetable soybean, and the sieve is kept horizontal, then the separating rate in the primary outlet is highest (Shieh and Chen 1987). The addition of a balance rack weight to the shaking separator adds stability (Shieh and Chen 1987). With the sieve in the horizontal position, and the vibrating frequency at 400 cpm, it can reach a 96.3% accuracy rate (Tzeng and Hsieh 1988; You et al. 1990). One separator has the capacity to support 10–15 threshers.

References

Esaki, Haruo. 1977. Binder and Combine, 308-360 (In Japanese).

Hsieh, Ching Chen, and Hsieh, Jun-Fu. 1985. Studies on vegetable soybean harvester. Journal of Agricultural Machinery Engineering, 19 (1), 5-16, Pingtung (In Chinese).

Hsieh, Ching-Chen. 1983. Study on vegetable soybean threshing machine (1). National Pingtung Institute of Agriculture AM-Report No. 3, 1-15. Pingtung (In Chinese).

1985. Study on vegetable soybean threshing machine (2) — Study on type of feeding chain, type and arrangement of threshing teeth, and type of sieve. 1985 Annual reports of Agricultural Machinery Research and Development, 102-115, PDAF (In Chinese).

Hsieh, Ching-Chen, and Chen, Kwang-Hwe. 1987. The study of a vegetable soybean shaking separator (1). Journal of Chinese Agricultural Engineering, 33 (2), 78-88, Taipei (In Chinese).

Su, Chung-Sheng and Wung, King-Swi. 1988. Studies on the performance of Monosem pneumatic precision seeder. Bulletin of National Pingtung Institute of Agriculture, 30, 84-97, Pingtung (In Chinese).

Tzeng, Kei-Hsiung, and Hsieh, Ching-Chen. 1988. Research on the operation capacities of vegetable soybean threshing, wind and sieve separating combine. 1988 Annual reports of Agricultural Machinery Research and Development, 186-187, PDAF (In Chinese).

Wung, King-Swi, and Su, Chung-Sheng. 1981. Studies on the manufacture and seeds distribution performance of pneumatic precision seeder. 1981 Annual Report of Agricultural Machinery Research and Development, 27-34, PDAF (In Chinese).

1981. Studies on the pneumatic seeder fertilizer. 1980 Annual reports of Agricultural Machinery Research and Development, 44-50, PDAF (In Chinese).

1984. Development of non-tillage pneumatic precision seeding and fertilizer machine. Journal of Chinese Agricultural Engineering, 30, 118-124, Taipei (In Chinese).

You, Ching-Chang, Chen, Kwang-Hwe, Tzeng, Kei-Hsiung, and Hsieh, Ching-Chen. 1990. Studies on the combine operation of vegetable soybean harvesting, threshing, and separating. PDAF (In Chinese).

Present and Potential Cropping Systems for Vegetable Soybean in Taiwan

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Abstract

Vegetable soybean is a traditional vegetable of Chinese people. There was no particular cropping pattern for vegetable soybean in Taiwan before the expansion of hectarage to meet export demands. The production and quality of vegetable soybean are sensitive to environmental conditions. Due to high population and limited arable land, agricultural production systems are highly intensified, with a high Multiple Cropping Index (MCI) in Taiwan. The production of vegetable soybean has to be incorporated into these existing cropping systems. Thus it is important to identify suitable production areas, seasons and cropping systems for vegetable soybean (1) to achieve high yield and good quality, and (2) to maintain and/or improve the total productivity of a given piece of land and the total profit to the farmer. The present and potential cropping systems for vegetable soybean are discussed from the point of view of marketing potential, climatic conditions, suitability in rice-based cropping systems, and the role in sustaining agricultural productivity. It was found that the developed and/or developing cropping systems for vegetable soybean in the central, central-southern and southern regions of Taiwan are appropriate systems. And there should be considerable potential for vegetable soybean to be grown during summer to substitute the second rice crop in these regions. In the eastern regions, it is possible to grow two crops of vegetable soybean after the first rice crop or spring maize in the Hualien area. In the Taitung area which has a similar temperature pattern to the Kaohsiung-Pingtung area, vegetable soybean can be grown in the spring or autumn and rotated with rice and/ or maize.

Introduction

Vegetable soybean is a traditional vegetable of Chinese people. In Taiwan, vegetable soybean was being grown long before export to Japan had begun (Fig. 1). Farmers often harvested immature soybean pods as vegetables during summer when typhoons hit Taiwan and the price of vegetables was high. Therefore, there was no particular cropping pattern for vegetable soybean in Taiwan before the expansion of hectarage for the export market. The vegetable soybean pods for export must be processed quickly, so their production is usually organized by a processing factory, and therefore specific cropping systems in specific areas must be followed.

The production and quality of vegetable soybean are sensitive to environmental conditions. Due to high population and limited arable land in Taiwan the agricultural production systems are highly intensified with a high Multiple Cropping Index (MCI) (Fig. 2). The production of vegetable soybean has to be incorporated into these existing cropping systems. Thus it is important to identify suitable production areas, seasons and cropping systems for vegetable soybean to achieve high yield and good quality and to maintain and/or improve the total productivity of a given area and profit to the farmer.

Climatic Conditions and Cropping Systems in Taiwan

Although Taiwan is a small island (36,000 km^2), its climatic conditions vary with season and location. It has an oceanic subtropical climate with a long, hot summer, and a short, mild winter, particularly in the southern region where the mean air temperature is higher than 20°C during winter (Fig. 3). Rainfall is abundant, varying from 1700 to 2000 mm/annum on the plain, and 3000 to 4000 in the mountain areas (Kuo 1978). Most rainfall comes during the summer, except in the northern part of the island where it is more evenly distributed year-round (Fig. 4).

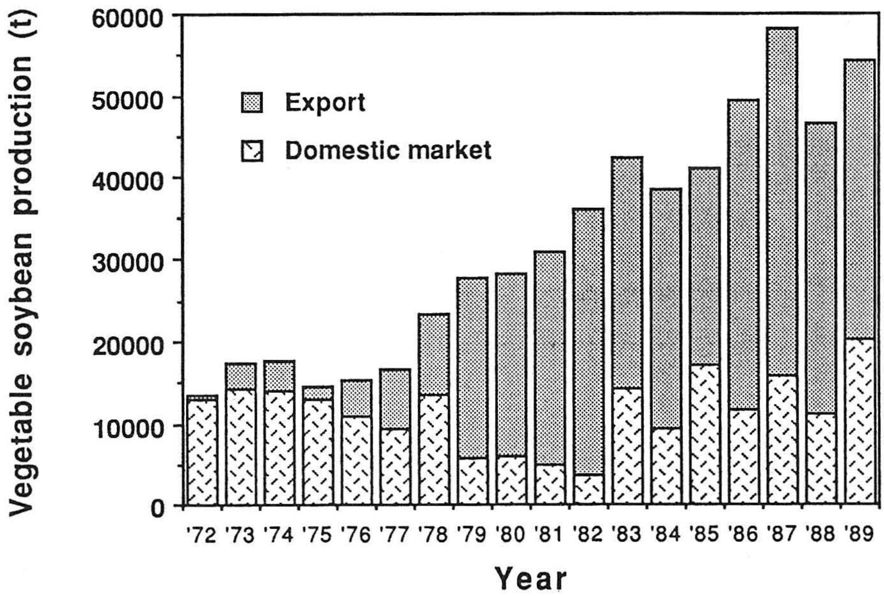

Fig. 1. Changes in volume of vegetable soybean for export and domestic markets.

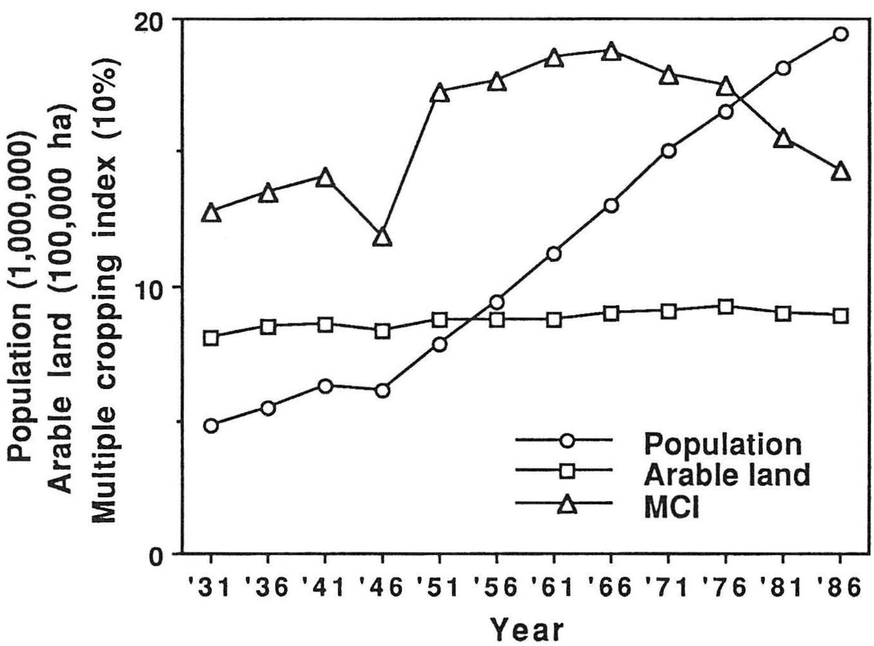

Fig. 2. Changes in population, arable land and Multiple Cropping Index (MCI) in Taiwan.

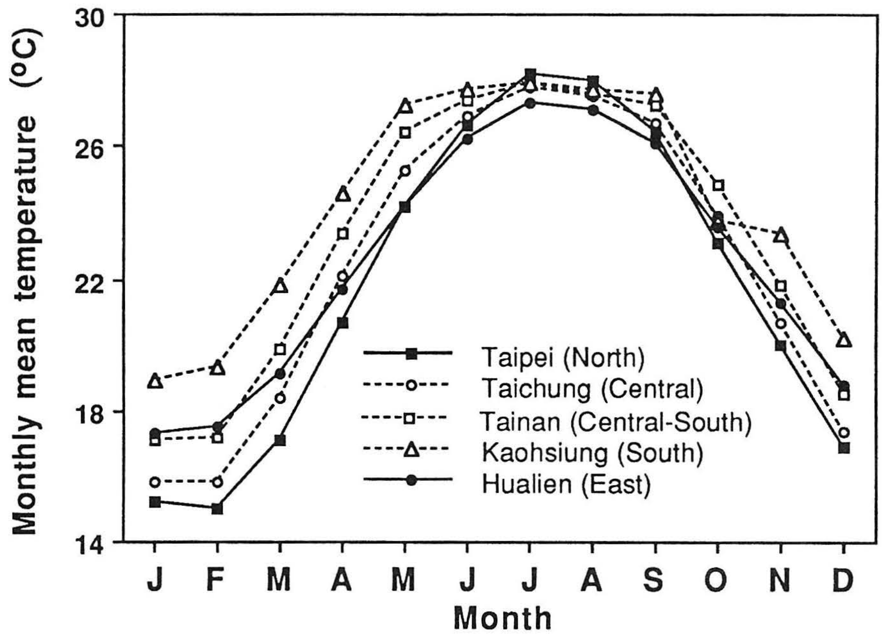

Fig. 3. Changes in temperature in different regions in Taiwan.

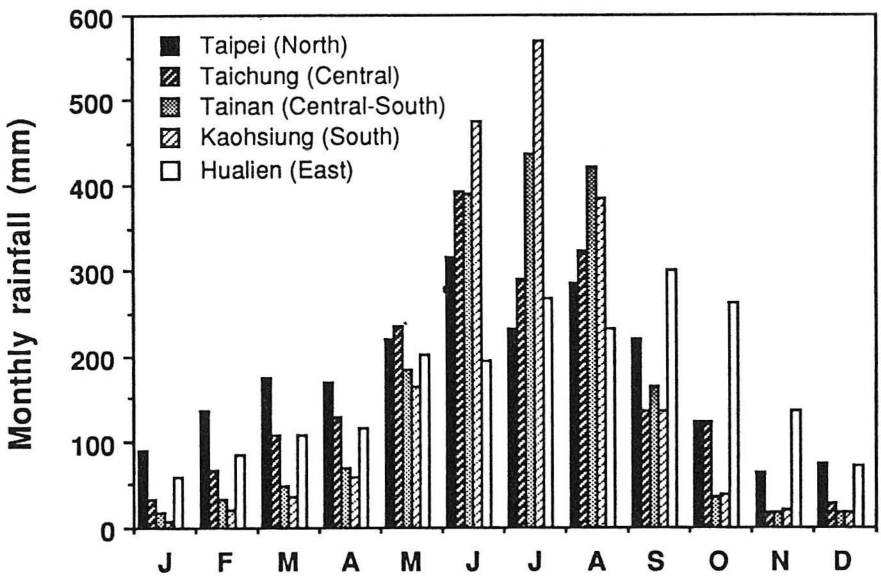

Fig. 4. Rainfall distribution in different regions in Taiwan.

Rice is the most important crop, and rice-based cropping systems are the most prevalent in Taiwan. Among total cultivated land of 894,974 ha in 1988, 483,514 ha or 54.0% were paddy fields. Based on the available amount of water for rice growth, the paddy field is classified into double rice cropping area (344,084 ha), first crop single rice cropping area (9722 ha), and second crop single rice cropping area (129,708 ha). The leading rice-based cropping systems for each category have been described by Cheng (1975) and Su (1981) as follows:

(1) Double rice cropping areas:

First crop of rice - (Summer catch crop) - Second crop of rice - (winter catch crop).

(2) First crop single rice cropping areas:

First crop of rice - Second crop of upland crops.

(3) Second crop single rice cropping areas:

First crop of upland crop - Second crop of rice - Winter upland crop. There are three main patterns included : one rice crop in every 1, 2, or 3 years.

With the change in the dietary habits of the people in Taiwan due to rapid economic development during recent years, rice consumption has declined since 1977, which resulted in a remarkable surplus in the rice supply. This overproduction of rice has become a critical problem, and converting the cropping patterns in the paddy field to decrease the production of rice is a major task of agricultural research and extension institutions. It is obvious that the production of vegetable soybean is mainly incorporated into rice-based cropping systems, either rotating with a rice crop or substituting for a rice crop.

Present Cropping Systems for Vegetable Soybean

The production of vegetable soybean in terms of maturity, marketable yield, shoot weight and the size of pod is significantly different in different cropping seasons. Results of six vegetable soybean entries in regional yield trials in the southern part of Taiwan showed that vegetable soybean had the highest marketable yield and largest pods in the spring season planting, though it also needs the longest growth duration among three season plantings (Table 1). The summer season planting had the lowest and the most unstable yield, and smallest pods. It is clear that summer conditions are not suitable for producing the high quality vegetable soybeans required by the Japanese market. As mentioned earlier, the vegetable soybean produced during the summer season is mainly for the domestic market to supplement the shortage of vegetables.

Table 1. The growth and yield of vegetable soybean during different seasons.

Season	Maturity (days)	Marketable yield (t/ha)	Shoot weight (t/ha)	No. of pods (per 515 g)
Spring	80.0±2.3	4.95±0.49	18.95±3.60	166±6
Summer	75.9±4.6	2.85±2.47	11.95±2.05	203±4
Autumn	70.9±2.6	4.45±1.48	9.60±3.53	178±2

Most vegetable soybean for export is grown in the southern part of Taiwan, Kaohsiung-Pingtung area (Kao-Ping), where the mean air temperature during winter is higher than 20°C and the rainfall mainly comes during summer. Vegetable soybean is suitable for both the spring and autumn season plantings in these areas. There are three major cropping systems for vegetable soybean in this region: The spring season planting starts in February and is rotated with the second rice crop and tobacco (Pattern 1, Fig. 5). The autumn season planting starts in October and is followed by snapbean and the second rice crop (Pattern 2, Fig. 5), or rotated with two crops of rice (Pattern 3, Fig. 5). In the central-southern part of Taiwan, Chiayi-Tainan areas, the production of vegetable soybean for export has started to expand, mainly in the spring season plantings and rotated with the second rice crop and maize (Pattern 4, Fig. 5). The summer vegetable soybean which rotated with maize and the first rice crop is mainly for the domestic market (Pattern 5, Fig 5). In the central part of Taiwan, Taichung area, vegetable soybean has recently been incorporated into the rice-based cropping systems. Vegetable soybean rotates with the second or the first crop rice, and potato (or other vegetables) in the spring or late summer season planting respectively (Patterns 6 and 7, Fig. 5). Vegetable soybean is also grown in the spring season planting to be rotated with melon and peanut in this region (Pattern 8, Fig. 5).

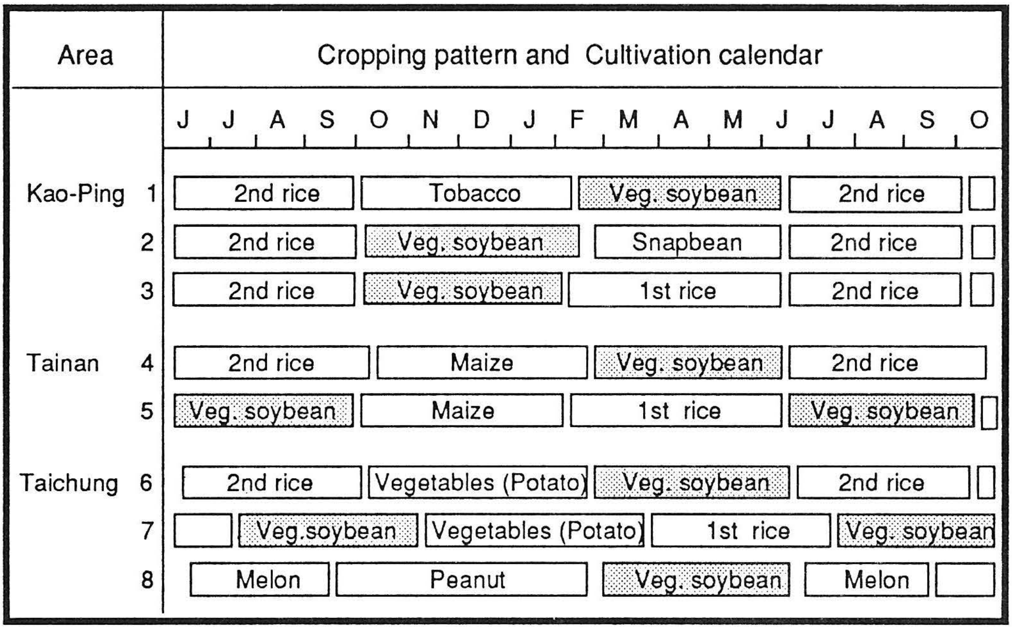

Fig. 5. The main cropping systems for vegetable soybean in Taiwan.

Potential Cropping Systems

With the potential for export, the production of vegetable soybean has increased dramatically during the last decade in Taiwan. However, the production is mainly concentrated in the Kaohsiung-Pingtung area which has the best environment for most crops during the dry season (with irrigation). It appears that due to the limited land and strong competition from other high-value crops such as adzuki bean (which needs less labor to harvest), more vegetable soybean will be grown in other parts of Taiwan. Since there is no arable land for expansion, a new crop such as vegetable soybean has to compete with available crops and incorporated into existing cropping systems to establish new cropping systems.

Any new cropping system should be considered for its profitability and sustainability. Profitability is based on marketing potential, yield, and quality of produce, and sustainability is related to the energy and finite resources utilized and the possibility of pollution caused by the system. To enhance profitability, high yield and good quality of produce should be achieved, and production costs should be reduced. For implementation, the appropriate varieties and production environments (i.e. location and season) should be identified, and the management techniques to reduce labor costs and improve efficiency of natural resources and inputs utilization should be developed. In Taiwan, intensive agricultural production systems are practiced to maintain high productivity of land. However, the fertility of the land is generally low due to overexploitation of nutrients and inappropriate management. Thus the role of a crop in the sustainability of a new cropping system needs to be emphasized. Therefore, to identify the potential cropping systems for vegetable soybean in Taiwan, its marketing potential, production environments, existing cropping systems, and its role in sustaining agricultural productivity should be considered.

Marketing potential

It is well known that there is a large market for vegetable soybean in Japan. However, the potential of vegetable soybean to be an important vegetable during summer in Taiwan, when there is a shortage in the supply of vegetables, has not been recognized. Although most of the vegetable soybeans produced in the summer season are not suitable for the Japanese market, they seem acceptable to local consumers due to differences in preparation and consumption.

Location and season

The vegetable soybean for local consumption during summer can be grown across the island without significant differences in yield, except the threat of typhoon damage. Because of its relatively short growing period, the possibility of typhoon damage is lower than for grain soybean. Even if it is hit by typhoons, it can be plowed into the field as green manure. Farmers in the central-south parts of Taiwan (Chiayi-Tainan areas) have well accepted this concept for soybean production and shifted the main soybean production areas in Taiwan (Table 2).

Table 2. Changes in hectarage and percentage of soybean production in Taiwan between 1983 and 1988.

	Total area	Cropping (%)		Region (%)	
Year	(ha)	Winter	Summer	Central-South	Southern
1983	5592	56.3	21.5	19.3	56.5
1988	7699	26.5	37.0	61.0	28.0

The quality of vegetable soybeans for export must be of a high standard in terms of pod size, color, etc. For the autumn season planting, due to the low temperatures during the late stages of vegetable soybean, only the southern region is suitable. In the central and central-southern regions, vegetable soybean has to be sown in late summer, when there is a risk of damage by typhoons and heavy rain. For the spring season planting, results of a network on soybean in Taiwan showed that both the central-southern and southern regions are suitable (Table 3). In the central areas, the soybean might suffer from low temperatures during the early stages, so it should not be sown before March. The temperature is too low for vegetable soybean in the northern region during spring. In the eastern areas (Hualien), soybean suffers from a high incidence of soybean rust during spring. In conclusion, the vegetable soybean for export should be grown in the areas south of Taichung in the spring and late summer season plantings, and in the southern region in the autumn planting.

Table 3. The yield of vegetable soybean, KS 10, in different seasons and locations in Taiwan.

Location	Yield (t/ha)	
	Spring	Autumn
Taichung	2.0	-
Tainan	2.9	1.6
Kaohsiung	2.7	2.6
Hualien	1.8	-
Taitung	1.5	-

Role of vegetable soybean in sustainable agriculture

The loss of nutrients from the soil due to the intensive agriculture in Taiwan is causing major concern. Leguminous crops with the ability to fix nitrogen have been considered as useful crops for improving the soil fertility in multiple cropping systems.

The analysis of soil total nitrogen in cropping systems studies at AVRDC showed that soybean and mungbean increased the soil total nitrogen, especially when they were grown in the summer season planting (Fig. 6). The vegetable soybean is harvested during the R_6 stage when there are more nutrients remaining in the shoots than at the R_8 stage when the grain soybean is harvested (Table 4). Thus more organic nitrogen can be returned to the soil and hence improve its fertility.

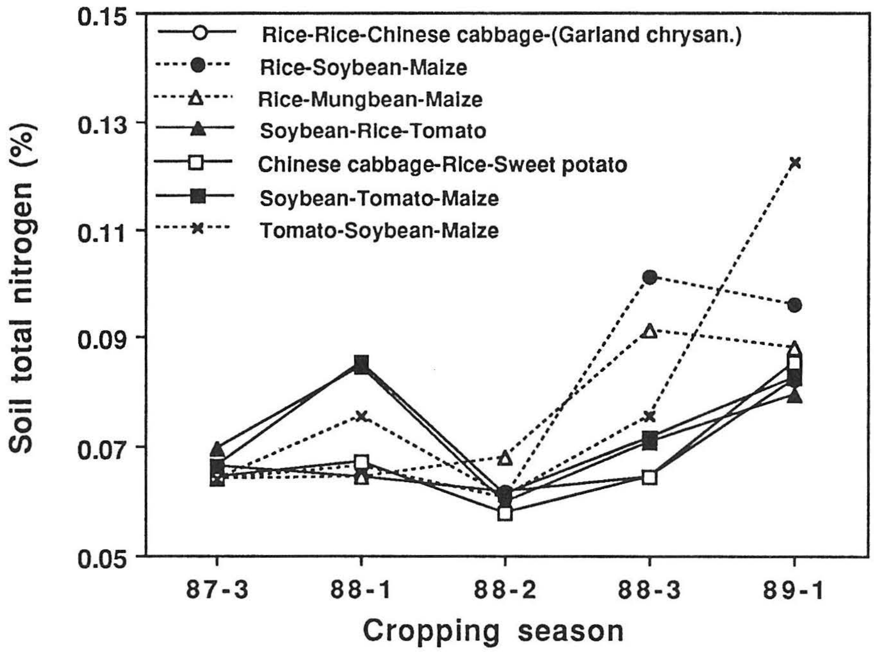

Fig. 6. Changes in soil total nitrogen in different cropping systems.

Table 4. Nitrogen yield from soybean during different growth stages.

Variety	Stage	Shoot		Pod	
		(kg/ha)	(%)	(kg/ha)	(%)
KS 8	R 6	101.6	39.6	155.2	60.4
KS 8	R 8	45.3	14.0	278.1	86.0
KS 10	R 6	78.8	30.2	182.4	69.8
KS 19	R 8	36.1	12.7	248.8	87.3

Due to the labor shortage and hence high labor costs in Taiwan, and the high labor requirements for harvesting vegetable soybean, mechanical harvesting is urgently needed. It is a reasonable expectation that all residues of vegetable soybean will return to the soil when mechanical harvesting is practiced. Therefore, the expansion of vegetable soybean production will play an important role in sustaining agricultural productivity in Taiwan in the near future.

Suitability in rice-based cropping systems

As mentioned earlier, most present cropping systems for vegetable soybean are rice-based, and since no adverse effect on either crop has been noticed, it appears that vegetable soybean is suitable for rotation with rice. Furthermore, results of a network on cropping systems during 3 years indicated that soybean can fit well into different rice-based cropping systems in different locations (Table 5). Vegetable soybean with a similar growing habit and shorter growth duration should be more suitable than grain soybean in these cropping patterns.

It seems that vegetable soybean is a potential crop to substitute and/or rotate with rice to reduce rice production and to maintain and/or improve soil fertility in Taiwan.

Table 5. Yield (t/ha) of soybean in different cropping patterns and locations in Taiwan, 1986-88.

Cropping pattern	Total growth duration (days)	Yield (t/ha)		
		Tainan	Kaohsiung	Hualien
Soybean-Rice-Maize	351±8	2.9±0.6		
Rice-*Soybean*-Maize	347±11	2.4±0.6		
Rice-Rice-*Soybean*	303±1		2.6±0.2	
Maize-Rice-*Soybean*	313±11		2.6±0.2	
Rice-*Soybean*	264±2			2.2±0.3

Potential Cropping Systems

Considering the above-mentioned factors, we found that the developed and/or developing cropping systems for vegetable soybean in the central, central-southern and southern regions of Taiwan (Fig. 5) are appropriate systems. There should also be great potential for vegetable soybean to be grown during summer to substitute for the second rice crop in these regions.

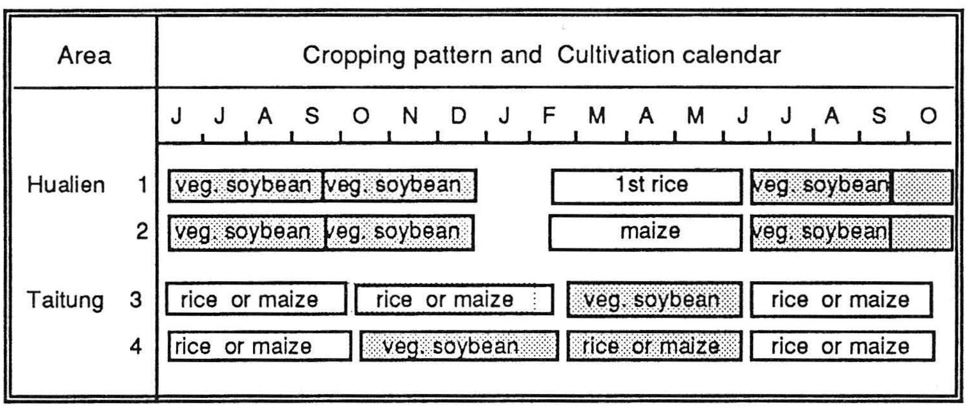

Fig. 7. The main cropping systems for vegetable soybean in eastern Taiwan.

In the eastern regions, it is possible to grow two crops of vegetable soybean after the first rice crop or spring maize in the Hualien area. In the Taitung area, which has a similar temperature pattern to Kaohsiung-Pingtung, vegetable soybean can be grown in the spring or autumn season planting and rotated with rice and/or maize (Fig. 7).

References

Cheng, C.P. 1975. Natural and technological factors contributing to multiple crop diversification in Taiwan. Philip. Econ. J.,14 (1 & 2), 47-63.

Kuo, W.S. 1978. The study on agriculture climate division in Taiwan. Central Weather Bureau, Taiwan, ROC. (In Chinese)

Su, K.C. 1981. High input cropping systems. Bull. Taichung Distr. Agric. Improvement Station. New Ser. 5, 107-120. Taichung, Taiwan, ROC.

Effect of Fertilizer Management and Rhizobia Inoculation on Yield and Quality of Vegetable Soybean

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Abstract

Vegetable soybean quality and yield can be improved through appropriate fertilizer management techniques and rhizobia inoculation. The best chemical fertilizer application rate was 60-80-60 kg N-P-K/ha; for soils with high phosphorus content, a 60-40-60 fertilizer was sufficient. Best results were obtained from chemical fertilizers applied as basal, at 15 days after sowing and at pod initiation stage in the following percentages: N, 50-30-20; P, 70-30-0; K, 50-50-0. The most successful organic fertilization, consisting of a 30-40-30 N-P-K fertilizer combined with either 2 t chicken manure/ha or 3 t fermented pig dung/ha increased graded pod yield by 13-25% (13-20% for fermented pig dung) and also pod quality. Although organic fertilizers also improved soil nutrient content, which may have contributed to almost all of the quality factors of soybean, the relationship between vegetable soybean taste and soil nutrient content must be studied to draw concrete conclusions. Rhizobia inoculation in conjunction with 20 kg N/ha increased both the number and weight of nodules. In addition, it not only increased graded pod yield by 14-22%, but also reduced fertilizer costs by $150/ha, raising overall profit by $480/ha.

Introduction

Vegetable soybean's growth period varies slightly with varieties and planting seasons. For the varieties presently cultivated in Taiwan the growth period of the spring planting is 70-80 days, and autumn planting 65-70 days. Because the growth period of vegetable soybean is short, and yields more revenue than grain crops such as adzuki bean, corn and peanut, the area planted to vegetable soybean has increased rapidly from 5012 ha in 1983 to 10,715 ha in 1988 (Dept of Agriculture and Forestry 1989). Vegetable soybean has thus become one of the major economic crops in southern Taiwan. Vegetable soybean was previously selected from grain soybean varieties that produced larger seeds, and management practices were those for grain soybean. However, with the development of new cultivars in recent years, the growth period of vegetable soybeans is shorter than that for grain soybean, and fertilizer management for vegetable soybean is different and needs to be made better known to the farmers.

In recent years, vegetable soybean produced in Taiwan has been mainly frozen and exported to Japan, gradually becoming an important processing product (Tsou et al. 1990). High quality is an essential requirement for the Japanese market. Improvements in appearance, texture and flavor are most important. The criteria of Japanese importers are: the standard graded pods should contain two or more seeds with pods 4.5 cm long and 1.3 cm wide, and be fresh green in color; pod weight of 515 g should be composed of less than 175 pods (Cheng 1990; Hung et al. 1990; Tsou et al. 1990). Because both quantity and quality of pods are important in increasing market price of vegetable soybean, considerable attention has been given to the potential of improving quality through cultural practices, e.g. irrigation, harvest time, fertilization management, planting time, etc. In Taiwan, where the living standards of people are quite high, the requirement of increasing yield has shifted to the urgent need of improving quality. This trend may be even stronger in Japan, which is also highly developed.

This study of the optimum fertilizer management practices for vegetable soybean looked at (1) the required amount and application time of chemical fertilizers; (2) effects of different organic fertilizers on yield and quality; (3) optimum nitrogen application rate together with rhizobia inoculation; and (4) the relations of soil chemical properties to quality of vegetable soybean.

Materials and Methods

Four series of experiments were conducted from autumn 1985 to spring 1990 in southern Taiwan and at AVRDC.

Experiment 1 was carried out in Chutien and Likang in both autumn 1985 and spring 1986. Treatments, fertilizer application rates and time are given in Tables 1 and 2. Cultivar Ukinosita was grown using a randomized incomplete block design with four replications.

Table 1. Fertilizer application rates (experiment 1-a).

Treatment No.	Application rates* of (kg/ha)		
	N	P	K
1	30	80	60
2	60	80	60
3	90	80	60
4	120	80	60
5	60	40	60
6	60	120	60
7	60	80	30
8	60	80	90

*N application was split into three times, 50% as basal, 30% at 15 days after sowing (DAS) and 20% at pod initiation stage; P was applied as basal only, and K was applied twice, 50% as basal and 50% at 15 DAS, respectively.

The second series of experiments was started in autumn 1987, continued in the spring and autumn of 1988, and ended in spring 1989. Split plot design was adopted in these experiments with two cultivars (Tzurunoko 205 (V1) and Kaohsiung No. 1 (V2)) as main plots and different organic fertilizer applications as subplots (Table 3). Quality evaluations of the graded pods were made after the autumn 1988 and spring 1989 trials.

The third series of experiments was initiated in autumn 1988 and ended in spring 1990. We used a randomized complete block design with three replications. Treatments included five organic fertilizers plus chemical fertilizers (Table 4). Cultivar Kaohsiung No. 1 pods harvested at R_6 stage were analyzed for dry matter, protein, fat, sugar, starch, fiber contents, hardness and pod color rating. Linear regressions were applied between soil properties and quality composition.

Table 2. Treatment times and ratio of fertilizer applications.

Treatment	Application ratio (%) at the time of			
	Basal	15 DAS	Flowering	Pod initiation
No.	N-P-K	N-P-K	N-P-K	N-P-K
1	100-100-100[a]	0-0-0	0-0-0	0-0-0
2	50-100-100	50-0-0	0-0-0	0-0-0
3	70-100-100	30-0-0	0-0-0	0-0-0
4	50-100-100	30-0-0	20-0-0	0-0-0
5	50-100-100	30-0-0	0-0-0	20-0-0
6	70-70-100	30-30-0	0-0-0	0-0-0
7	70-100-50	30-0-50	0-0-0	0-0-0
8	70-100-50	30-0-30	0-0-20	0-0-0

[a]Application rates of N, P and K were 60, 80 and 60 kg/ha, respectively.

Table 3. Chemical and organic fertilizer applications.

Treatment	Chemical fertilizer			Organic fertilizer	
No.	N	P	K	Type	Amounts (t/ha)
				Experiment 2a — 1988	
1	60	80	60	Check	0
2	60	80	60	Seaweed extract	FS[a]
3	30	40	30	Chicken manure	2
4	30	40	30	Garbage compost	6
5	30	40	30	Pig dung	3
6	30	40	30	Fu-Ming-Shu[b]	4
				Experiment 2b — 1989	
1	60	80	60	Check	0
2	60	80	60	Seaweed extract	FS
3	30	40	30	Chicken manure	2
4	0	0	0	Chicken manure	4
5	30	40	30	Garbage compost	6
6	0	0	0	Garbage compost	12
7	30	40	30	Pig dung	3
8	0	0	0	Pig dung	6

[a]Seaweed extract is a commercial product containing several kinds of trace elements; foliar sprayed three times at 20 DAS, pod initiation and pod filling stages, respectively.
[b]Fu-Ming-Shu is a commercial organic fertilizer.

In the fourth series of experiments, the effect of rhizobia inoculation was studied from spring 1988 to 1989 at six locations. The main plot consisted of cultivars Tzurunoko 205 and Kaohsiung No. 1. The subplot received varying N rates with rhizobia inoculation (Tables 5–6). The reduction of fertilizer cost and the degree of profit were computed.

Results and Discussion

Effects of fertilizer application rate on yield

The optimum nitrogen application rate is 60 kg/ha for both spring and autumn plantings in terms of graded pod yield (Table 7). When the nitrogen application rate exceeded 60 kg/ha, graded pods of vegetable soybean decreased with the increase of nitrogen application rate. The optimum phosphorus application rate was 80 kg/ha for both spring and autumn plantings for above-ground fresh weight and yield of graded pods (Table 7). However, the yield increase of autumn planting was insignificant. If vegetable soybean is cultivated on sandy loam and silty loam with relatively high levels of phosphorus in the soil, application of 40 kg/ha will be sufficient to supply phosphorus needs during the growth period. Also, experimental results showed that for both spring and autumn plantings, 60 kg K/ha is appropriate (Table 7).

Table 4. Experiments using five organic fertilizers conducted at AVRDC (autumn 1988-spring 1990

Planting	Treatment	Organic fertilizer (t/ha)		Chemical fertilizer (kg/ha)		
	No.	Type	Amount	N	P	K
Autumn 1988	1	Sugarcane compost	30	60	60	80
and	2	Cattle dropping	3	60	60	80
Spring 1989	3	Castor-oil granule	0.5	60	60	80
	4	Taiwan fertilizer #1	3	60	60	80
	5	Taiwan Sugar fert. #3	3	60	60	80
	6	Control	0	60	60	80
Summer 1989	1	Sugarcane compost	40	42	0	0
	2	Cattle dropping	20	50	0	0
	3	Castor-oil granule	0.5	42	55	55
	4	Taiwan fertilizer #1	20	42	0	0
	5	Taiwan Sugar fert. #3	20	42	0	0
	6	Control	0	60	60	60
Autumn 1989	1	Sugarcane compost	40	60	82.5	60
	2	Sugarcane compost	80	60	82.5	60
	3	Sugarcane compost	120	60	82.5	60
	4	Taiwan fertilizer #1	15	60	82.5	60
	5	Taiwan fertilizer #1	30	60	82.5	60
	6	Control	0	60	82.5	60
Spring 1990	1	Sugarcane compost	40	20	30	20
	2	Sugarcane compost	80	20	30	20
	3	Sugarcane compost	120	20	30	20
	4	Control	0	60	82.5	60
	5	Chemical fertilizer	0	120	165	120
	6	Chemical fertilizer	0	20	30	20

Table 5. Treatments of N fertilizer with rhizobia inoculation (experiment 4-a, spring 1988).

Subplot: chemical fertilization and rhizobia inoculation

	Chemical fertilizer			
	N	P	K	Rhizobia inoculation
1	Commonly used by farmers[a]			Without
2	0	63	60	With
3	21	63	60	With

[a]Experiments were conducted at two Chao-Cho locations: N-P-K applied by the two farmers were 187-74-102, and 282-272-208 kg/ha, respectively.

Table 6. Treatments of N fertilizer with rhizobia inoculation (experiment 4-b, autumn 1988 and spring 1989).

Subplot: chemical fertilization and rhizobia inoculation

	Chemical fertilizer			
	N	P	K	Rhizobia inoculation
1	Commonly used by farmers[a]			Without
2	60	60	60	Without
3	0	60	60	Without
4	0	60	60	With
5	20[b]	60	60	With
6	20[c]	60	60	With

[a]Experiments were conducted at six locations in both seasons; N, P and K applied by the six farmers ranged from 144 to 200, 145 to 180 and 72 to 226 kg/ha in autumn 1988, and from 75 to 124, 42 to 321, and 96 to 208 kg/ha in spring 1989, respectively.
[b]N applied as top dressing.
[c]N applied as basal.

Table 7. The effect of N, P and K applications on the yield of vegetable soybean (experiment 1).

	Graded pod yield (t/ha)							
	Autumn 1985				Spring 1986			
	Chutien	Likang	Average	Index	Chutien	Likang	Average	Index
Nitrogen (kg/ha)								
30	3.2	4.8	4.0	100	4.8	5.6	5.2	100
60	3.6	5.5	4.6	115	5.7	5.9	5.8	112
90	3.3	5.3	4.3	108	5.3	5.6	5.4	105
120	3.4	5.1	4.3	107	4.9	5.0	5.0	96
Phosphorus (kg/ha)								
40	3.3	5.6	4.4	100	5.4	5.3	5.4	100
80	3.6	5.5	4.6	103	5.7	5.9	5.8	108
120	3.4	5.6	4.5	101	4.5	5.4	5.0	93
Potassium (kg/ha)								
30	3.5	5.3	4.4	100	5.2	5.3	5.2	100
60	3.6	5.5	4.6	104	5.7	5.9	5.8	111
90	3.5	5.4	4.5	102	5.0	5.7	5.4	102

L.S.D. not significant at 5% level.

Since vegetable soybean is treated as immature soybean pods, there are differing opinions on whether high vegetable soybean yield requires appropriate nitrogen fertilizer. Some researchers support this notion (AVRDC 1985; Kao 1984; Lathwell and Evans 1951), and others feel that application of nitrogen fertilizer does not necessarily increase soybean yield (Bezdicek et al. 1974; Hinson 1975; Johnson et al. 1975; Lyons and Earoey 1952; Welch et al. 1973). There are also cases in which soybean yield increased through nitrogen application (AVRDC 1976; Brevedan et al. 1977; Cheng 1984; Cheng and Huang 1989; Kao 1984; Ohlrogge 1966). Cheng (1984) reported that 40 kg N/ha was needed for grain soybean cultivar Kaohsiung 8. Although the nitrogen application rate of these experiments was higher than the 40 kg/ha by one-third, the growth period for vegetable soybean was only about 65-80 days, and the growth in the initial stage was slow, thus probably requiring more nitrogen fertilizer.

Phosphorus tends to be affected by all sorts of physicochemical properties in the soil. In red soil containing high aluminum and iron, phosphorus is easily precipitated as insoluble ferric phosphate and aluminum phosphate, resulting in a decrease of phosphorus availability. Therefore the application rate of phosphorus has to be increased (Wang and Wu 1990). Cheng and Chen (1985) pointed out that 120 kg P/ha applied in general soils and highly acid soils produced the highest yield. In both our spring and autumn plantings, the phosphorus content in one field was almost double that in the other (Table 3), hence the phosphorus application required was also different. In soil with high available phosphorus, the P application rate should be only half the amount used for soil low in phosphorus.

Potassium is a highly soluble fertilizer, and relatively easy to release in the soil. In Wang's (1975) soybean trial in Pingtung slate alluvial soil, potassium application rates were 30-60 kg/ha in soils that had available potassium of 15-35 ppm, and 60-90 kg/ha in soils with available potassium below 15 ppm (Egner method; Wang 1975). Therefore, the recommendation of 60 kg K/ha generally agreed with Wang's practice.

Effects of fertilizer application time on yield

The application of 50% nitrogen fertilizer as basal, 30% at 15 days after sowing (DAS) and 20% at pod initiation stage (PIS) produced better graded pod yield than other treatments in both spring and autumn plantings (Table 8). The yield increases were about 11 and 6%, respectively, in treatments with nitrogen when the full amount was applied as basal and in treatments with half as basal, and the other half applied at 15 DAS. Based on AVRDC's research on nitrogen application rates for soybean to secure sufficient pod and seed numbers, nitrogen should be applied at 4-6 weeks after germination (AVRDC 1985). Because both pod and seed numbers are important yield components (Shanmugasundaram et al. 1990), and to obtain maximum yield of vegetable soybean, one-half of the nitrogen should be applied as basal and the remaining half at the R_1 stage (Hung 1991) at the latest.

Applying 70% of phosphorus as basal and 30% at 15 DAS increased graded pod yield by around 3% for both spring and autumn plantings (Table 8). Cheng and Chen (1985) recommended that application of phosphorus in slightly alkaline soil and in general soils all as basal is better than splitting it into two applications. But in strong acid soils, application of phosphorus at two different times (60% as basal, and 40% as top dressing) is superior (Cheng and Chen 1985). Results obtained in our trials were similar.

When application time of potassium was 50% as basal and 50% as top dressing at 15 DAS in both spring and autumn plantings, yield increase was around 2-5% (Table 8). The increase was even larger with 2–3 applications of potassium. These results generally agreed with Cheng and Huang's (1989) data showing that the application time of potassium for soybean Kaohsiung No. 10 was 100% as basal or 50% as basal and 50% as top dressing.

Effect of different organic fertilizers on yield and graded pod ratio

The graded pod yield, summarized from experimental results conducted in four plantings at four locations over 2 years, was highest in treatments with half chemical fertilizer (N-P-K = 30-40-30 kg/ha) and 2 t/ha of chicken manure. Compared with the check plot (N-P-K = 60-80-60 kg/ha), the yield increased 25.4% in autumn 1987, 16.7% in spring 1988, 18% in autumn 1988 and 13.7% in spring 1989. The second highest yield was in treatments with half chemical fertilizer (N-P-K = 30-40-30 kg/ha) and 3 t/ha of fermented pig dung compost, which respectively increased the yield 20.3% in autumn 1987, 18.6% in spring 1988, 14.1% in autumn 1988, and 13.4% in spring 1989 compared with the check.

Table 8. Effect of nitrogen application time on the yield of vegetable soybean (experiment 1).

N% applied at the time* of				Graded pod yield (t/ha)**							
				Autumn 1985				Spring 1986			
Basal	15 DAS	FL	PIS	Chutien	Likang	Average	Index	Chutien	Likang	Average	Index
100	0	0	0	4.8	5.1	4.9	100	4.8	5.7	5.3	100
50	50	0	0	5.0	5.4	5.2	106	5.1	6.0	5.6	106
70	30	0	0	5.0	5.6	5.3	107	5.4	5.9	5.7	108
50	30	20	0	5.1	5.6	5.3	108	5.6	6.0	5.8	110
50	30	0	20	5.2	5.8	5.5	112	5.5	6.4	5.9	113
P% applied at the time* of											
Basal	15 DAS										
100	0			5.0	5.6	5.3	100	5.4	5.9	5.7	100
70	30			5.3	5.6	5.4	103	5.5	6.1	5.8	103
K% applied at the time* of											
Basal	15 DAS	FL									
100	0	0		5.0	5.6	5.3	100	5.4	5.9	5.7	100
50	50	0		5.1	5.9	5.5	105	5.4	6.2	5.8	102
50	30	20		4.9	5.5	5.2	98	4.7	5.2	4.9	87

*15 DAS: 15 days after sowing; FL: flowering stage; PIS: pod initiation stage.
**L.S.D. not significant at 5% level.

Lin and Liau (1990) reported that application of pig dung compost had better effects on plant height, pod yield, graded pod weight and thousand-seed weight than the check without compost. Hou et al. (1991) also showed that an increase in yield with the application of organic fertilizers such as pig dung and cow dung was mainly due to the enlargement of yield components such as pod number, pod weight and seed weight. Our results generally agreed with those of Lin and Liau (1990) and Hou et al. (1991).

The graded pod ratio results were similar, with half chemical fertilizer and 2 t/ha chicken manure or 3 t/ha fermented pig dung both performing best. Total pod ratio (pod weight/total above-ground fresh weight (stem + leaf + pod)) was most closely related to pod yield. Therefore, comparing effects of organic fertilization in terms of total pod ratio, graded pod ratio and graded pod yield, applying half chemical fertilizer (N-P-K = 30-40-30 kg/ha) with chicken manure at 2 t/ha and fermented pig dung at 3 t/ha are all better than applying fertilizer only, or applying more chicken manure, pig dung, garbage compost, and other commercial organic fertilizer products.

Effects of different organic fertilizers on quality

Quality sensory evaluations of the 1988 and 1989 trials were carried out. The evaluations showed that the fullness of pod shape was 100% satisfied in treatments with half fertilizer plus 3 t/ha of fermented pig dung compost. The greenness of pod was rated best at 100% in 1988 and 90% in 1989, respectively, in plots with half fertilizer plus 2 t/ha of chicken manure. Hardness and softness of seeds were rated best with half fertilizer plus 3 t/ha of fermented pig dung compost. Both treatments produced nearly the same good flavor. Sweetness, either judged by tasting or measured by instrument, was best with half fertilizer plus 2 t/ha of chicken manure. Lin and Liao (1990) reported that application of pig dung compost can increase the sweetness of vegetable soybean seeds by 2-3 degrees of Brix. Obviously applying chicken manure and fermented pig dung compost contributes to the flavor and sweetness of vegetable soybean seeds.

Relations of soil properties with quality

Effects of five kinds of organic fertilizer application on vegetable soybean were not pronounced when cultivated at AVRDC. However, yield of five plantings reached 8–10 t/ha which was almost twice as much as that obtained in southern Taiwan. Graded ratio of pod yield was as high as 70-85 % in all treatments. This suggests that soil fertility in the experimental field was sufficiently high, hence fertilization was not a limiting factor for promoting vegetable soybean yield.

Although organic fertilizers did not show their effects on soybean yield, they did improve the nutrient concentration in soils collected before sowing and at harvest. The increments of soil nutrient revealed the composition of organic fertilizer.

After harvest, vegetable soybean seeds were analyzed for some quality-related compositions, such as pod color rating, dry matter, protein, sugar, and starch content. Selected quality properties of the 1989 spring and autumn plantings are presented in Table 9. Most of the quality properties were not significantly affected by organic fertilizer application.

Table 9. Effect of organic fertilizer application on selected quality properties of vegetable soybean (spring and autumn 1989).

Treatment Organic fertilizer (t/ha)	Pod color rating	Dry matter (%)	Protein (%)	Fat (%)	Sugar (%)	Starch (%)	Crude fiber (%)
Spring 1989							
Sugarcane compost, 30	4.95	34.6	40.4	19.7	10.3	9.6	4.6
Cattle dropping, 3	5.03	30.7	41.1	19.7	10.2	10.0	4.3
Castor-oil granule, 0.5	4.94	34.7	40.9	20.0	9.9	10.0	4.4
Taiwan fertilizer #1, 3	4.74	34.7	40.9	19.9	9.9	10.0	4.6
Taiwan Sugar fert. #3, 3	4.97	34.3	40.4	19.8	10.0	9.9	4.5
Control	4.85	34.8	41.1	19.9	9.9	9.9	4.5
Autumn 1989							
Sugarcane compost, 40	4.36	32.0	40.2	17.0	13.7	9.5	4.2
Sugarcane compost, 80	4.43	31.9	40.1	17.1	13.5	9.7	4.2
Sugarcane compost, 120	4.52	32.0	40.3	16.9	13.6	9.3	4.3
Taiwan fertilizer #1, 15	4.48	32.0	39.5	17.4	13.3	9.6	4.3
Taiwan fertilizer #1, 30	4.38	31.4	38.7	16.9	13.7	10.0	4.4
Control	4.43	32.3	40.3	17.1	13.6	9.3	4.3

Linear regression was applied to the data of the five trials and correlation coefficients between quality composition and soil properties were determined. Negative correlations existed between soil properties and pod color rating, contents of dry matter, protein and fat, and hardness. On the contrary, most positive coefficients were obtained between sugar and fiber contents and soil nutrients. Since the relations between the sensory taste of vegetable soybean and the detectable chemical compositions have not been well established, it is difficult to determine the effect of soil nutrient concentration on quality of vegetable soybean. In general, the lower the color rating value, oil and starch fiber contents and hardness, and the higher the value of protein and sugar contents, the better the quality. It seems that improving soil nutrient concentration through organic fertilization may favor all the quality components except the protein and fiber content. How to determine the balance point that favors all eating qualities may need further study.

Effects of rhizobia and N on nodule number

Effective nodule number and nodule ratio of vegetable soybean tended to increase with rhizobia inoculation, but they also decreased with the increase of nitrogen application. Surveys of nine locations in 1988 autumn plantings at 30 DAS indicated that the effective nodule ratio with rhizobia inoculation and 20 kg N/ha as top-dressing was highest, i.e. 55.3%, which was 14.6% higher than farmers' common practice area, and 12.6% higher than the check plot (N-P-K = 60-60-60 kg/ha). However, effective nodule number at 45 DAS became highest in treatments with rhizobia inoculation plus P and K application only (N-P-K = 0-60-60 kg/ha). Obviously, effective nodule number gradually decreased after additional N top dressing.

Kao and Lin (1984) pointed out that applying 20-50 kg/ha of nitrogen resulted in dark green leaf color, scarcity of nodule number, and low effective nodule ratio. Wang (1988) reported that rhizobia inoculation without nitrogen application had 30 times higher nodule number than that without inoculation. However, with 40 kg/ha of nitrogen application and rhizobia inoculation nodule number increased by 14 times only, which is significantly much less than inoculation without N application. Hung (1991) also showed that nodules in treatments with rhizobia inoculation and without N application were higher in number and heavier, but with nitrogen application, nodules were lower in number and lighter, and the number decreased with increments of N application.

Investigations on graded pod yield, fertilizer cost and profit increase by rhizobia inoculation

Generally, farmers who grow vegetable soybean were controlled by the merchants; therefore, the amount of fertilizer applied was also decided by merchants. According to a survey of farmers' fertilizer application amount in vegetable soybean production areas in Taiwan, the fertilizer application rate was obviously much higher than the recommended rate (N-P-K = 60-60-60 kg/ha), e.g., 1.8-3.7, 1.8-3.0 and 1.4-2.7 times higher in N, P and K, respectively. Apparently, farmers' investment in fertilizer for the cultivation of vegetable soybean was astonishingly high. Such high rates of fertilizer application accelerate the acidification of fields, and excess chemical fertilizers that cannot be completely absorbed by crops will pollute groundwater. Therefore, it is urgent to guide farmers to use rhizobia inoculation instead of chemical fertilizer for cultivation of vegetable soybean.

According to the results of three trials in the spring of 1988, rhizobia inoculation with 21 kg/ha of nitrogen as basal increased graded pod yield on average by 14.3% more than the two farmers' common fertilizer application without inoculation; the fertilizer cost reduced by NT$7006 (NT$27.2 = US$1); in total the profit increased by NT$13,850/ha. In the 1988 autumn planting, average graded pod yield at seven locations with rhizobia inoculation and 20 kg/ha of nitrogen as basal increased 18.2% more than farmers' common fertilizer application method, and the fertilizer cost reduced by NT$5880; in total the profit increased by NT$13,861/ha. However, treatment by rhizobia inoculation only without nitrogen also increased profit by NT$13,181/ha.

In the spring 1989 planting, treatment with rhizobia inoculation plus 20 kg/ha of nitrogen top dressed at 20 DAS performed best, increasing graded pod yield by 22.7% more than farmers' common practice; the fertilizer cost reduced by NT$3863, and the profit increased by NT$14,429/ha. It was obvious that rhizobia inoculation produced significantly higher yield and more benefit than farmers' common application method. Many reports confirmed that rhizobia inoculation can better ensure an increase of soybean yield (AVRDC 1976; Kao 1984; Wu 1958, 1959, 1964; Young et al. 1988).

Because there was no replication in observation fields, variance analysis could not be done for the same field. Analyzing the coefficient of variations (CV) from yield data of seven locations in 1988 autumn plantings and six locations in 1989 spring plantings showed that the CV is 10.2 and 11.1 for both plantings, respectively. Further analysis of variance for pod yield showed significant differences between rhizobia inoculation and no rhizobia inoculation.

Conclusions

(1) For optimum chemical fertilizer rates, 60-80-60 kg/ha of N-P-K is applicable for both spring and autumn planting. In soils with high phosphorus fertility, 40 kg P/ha will be sufficient.

(2) The suitable application time is as follows: for spring planting, 50% of N should be applied as basal, 30% at 15 DAS and 20% at PIS; 70% of P as basal and 30% at 15 DAS; 50% of K as basal and 50% at 15 DAS. For autumn planting, the same method is applicable, or N can be split into 50% as basal and 50% at 15 DAS; P is applied as basal only.

(3) Applying 2 t/ha of chicken manure or 3 t/ha of fermented pig dung with 30-40-30 kg/ha of N-P-K increased the graded pod yield by 13-25% and 13-20%, respectively. They also improved the quality of vegetable soybean in terms of increasing the fullness of pod, pod color, taste and sweetness.

(4) Inoculating rhizobia increased weight of nodules and the effective numbers of nodules. Rhizobia inoculation and 20 kg N/ha applied as basal increased the graded pod yield by 14–22%. It also saved around US$150/ha on fertilizer cost. The total profit increase of rhizobia inoculation was around US$480/ha.

Considering fertilizer application rate, cost, consumption of natural resources, possible pollution of groundwater, etc., the best fertilization and management method for vegetable soybean cultivation would be rhizobia inoculation, which enables vegetable soybean to absorb and utilize the nitrogen in the air through nitrogen fixation. Furthermore, application of 2 t/ha of chicken manure or 3 t/ha of pig dung compost with 30-40-30 kg/ha of N-P-K as basal seems to be appropriate.

(5) In soil with high fertility, the soil chemical properties were positively correlated with sugar and fiber content, but negatively with protein, dry matter content, hardness and pod color rating. These correlations deserve further study.

References

Asian Vegetable Research and Development Center. 1976. Soybean report 1975. Shanhua, Taiwan, Republic of China. 68 p.

1985. Rational nitrogen fertilization for soybean. Annual Report, 131–150.

Bezdicek, D.F., Mulford, R.F., and Maggee, H.H. 1974. Influence of organic nitrogen on soil nitrogen, nodulation, fixation and yield of soybeans. Soil Sci. Soc. Am. Proc., 38, 268.

Brevedan, R.E., Egli, O.B., and Leggett, J.E. 1977. Influence of N nutrition on total N, nitrate and carbohydrate levels in soybeans. Agron. Jour., 69, 965.

Cheng, J.H. 1984. Study on the optimum fertilizer rates of soybean new variety KS 8. Soil and Fertilizer Experiment Report published by the Department of Agriculture and Forestry, Taiwan Provincial Government, 35–47.

1990. Study on the effects of organic fertilizers on the yield and quality of vegetable soybean. Soil and Fertilizer Experiment Report published by the Department of Agriculture and Forestry, Taiwan Provincial Government, 208–222.

Cheng, J.H., and Chen, F.I. 1985. Phosphorus to the efficiency of the soybean yield in different soil condition. Soil and Fertilizer Experiment Report published by the Department of Agriculture and Forestry, Taiwan Provincial Government, 95–103.

Cheng, J.H., and Huang, C.H. 1989. Study on the optimum fertilizer rates and application time of soybean new variety Kaohsiung Selection 10. Soil and Fertilizer Experiment Report Published by the Department of Agriculture and Forestry, Taiwan Provincial Government, 132–150.

Department of Agriculture and Forestry, Taiwan Provincial Government. 1989. Crop Production. 6. Vegetables (15) Peppers, kidney beans, peas, vegetable soybean and other fruit vegetables. Taiwan Agricultural Yearbook, 48–49.

Hinson, K. 1975. Nodulation responses from nitrogen applied to soybean half-root systems. Agron. Jour., 67, 799–804.

Hou, C.L., Chi, C.H., and Chou K.C. 1991. Studies of the effect of filter-cake and composts on the growth and yield of vegetable soybean. 1990 Soil and Fertilizer Experiment Report. Seminar paper (unpublished).

Hung, A.T. 1991. Studies on the fertilization technique after inoculation and the Rhizobia and V.A. Mycorrhiza of Soybean (in press).

Hung, A.T., Lo, R.S., and Hsu, C.M. 1990. Demonstration and extension of biofertilizer on vegetable soybean production in Kao-Ping area. Proceedings of a symposium on soil and fertility management of legume crops published by Kaohsiung District Agricultural Improvement Station, 234–251.

Johnson, J.V., Welch, L.F., and Kurtz, L.T. 1975. Environmental implication of N fixation by soybeans. Jour. Environ. Qual., 4, 303–306.

Kao, T.C. 1984. Study on the effect of denitrifying *Rhizobium japonicum* on soybean-maize cropping system and soil fertility. Bulletin of Taichung District Agricultural Improvement Station, 9, 57–67.

Kao, T.C., and Lin, A.C. 1984. Ecological studies on nitrogen fixation of soybean nodules in Kao-Ping area of the south Taiwan investigations on nodular development and distribution of soybeans. National Science Council Monthly, 11 (12–2), 1409–1418.

Lathwell, D.J., and Evans, E.E. 1951. Nitrogen uptake from solution by soybean at successive states of growth. Agron. Jour., 43, 264.

Lin, C.K., and Liao, C.J. 1990. Studies on the effect of different organic manure for the yield and quality of vegetable soybean. Soil and Fertilizer Experiment Report published by the Department of Agriculture and Forestry, Taiwan Provincial Government, 200–207.

Lyons, J.C., and Earoey, E.B. 1952. The effect of ammonia nitrate application to field soils on nodulation, seed yield and nitrogen and soil content of the seed of soybeans. Soil Soc. Amer. Proc., 16, 159–163.

Ohlrogge, A.J. 1966. Mineral nutrition of soybeans. *In* Norman, A.G. (ed.) The soybean. New York: Academic Press, 126–158.

Tsou, S.C.S., Wu, M.H., Hong, T.L., and Tsay, J.S. 1990. Cultural management on yield and quality of vegetable soybean. Proceedings of a symposium on soil and fertility management of legume crops published by Kaohsiung District Agricultural Improvement Station, 135–146.

Shanmugasundaram, S., Chen, K.F., Chen, L.F., and Azran, T. 1990. Response to different levels of management inputs in soybean. Proceedings of a symposium on soil and fertility management of legume crops published by Kaohsiung District Agricultural Improvement Station, 19–25.

Wang, C.T. 1988. Effects of rhizobia and glomus inoculation on soybean. Soil and Fertilizer Experiment Report, published by the Department of Agriculture and Forestry, Taiwan Provincial Government, Republic of China, 102–109.

Wang, Y.P. 1975. Studies on the effect of R, K and Mo contents of soil on response of soybean to application of P and K fertilizers and inoculation. Journal of Agriculture & Forestry, 24, 121–162.

Wang, Y.P., and Wu, J.T. 1990. The nutrient and its fertilizer management of soybean. Proceedings of a symposium on soil and fertility management of legume crops published by Kaohsiung District Agricultural Improvement Station, 47–60.

Welch, L.F., Boone, L.V., Chambliss, C.G. 1973. Soybean yields with direct and residual nitrogen fertilization. Agron. J., 65, 547–550.

Wu, M.H. 1958. Studies on rhizobia inoculation of legumes in Taiwan. Journal of Agriculture & Forestry, 7, 131–178.

1959. A selection of good strains of *Rh. japonicum* by field experiment. Journal of Agriculture & Forestry, 8, 83–87.

1964. A selection of a superior strain of *Rhizobium japonicum* by field experiment. Journal of Agriculture & Forestry 13, 11–13 .

Young, C.C., Juang, T.C., and Cho, C.C. 1988. Effect of Rhizobia and VA mycorrhiza inoculation on nodulation, symbiotic nitrogen fixation and yield of soybean in subtropical-tropical fields. Biology and Fertility of Soils (Germany), 6, 165–169.

Plant Protection Technology for Vegetable Soybean

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Abstract

Vegetable soybean is a very important crop in Taiwan, especially in terms of export value. Research to control diseases, insects, and weeds has been limited, considering the value of the crop. Studies have identified the important diseases of vegetable soybeans: downy mildew, rust, and *Rhizoctonia* damping-off. There are no resistant cultivars to these diseases. Fungicides such as mancozeb, maneb, or zineb are used to control downy mildew and rust. Other fungicides such as oxycarboxin, triforine, and triclopyr are registered for the control of soybean rust. Pod diseases occasionally can be important and detrimental both to yield and quality. Beanflies and lepidopterous and coleopterous defoliators, stink bugs, and lima bean podborer are important insect pests of soybean. Sources of resistance/tolerance to all four categories are available in grain soybean, but at present all vegetable soybean cultivars grown are susceptible. At present farmers in Taiwan use only chemical insecticides to combat insect pests of soybean. The potential exists for integration of various control measures to develop an integrated pest management program which will control these pests on a sustainable basis without resorting to the use of toxic insecticides. Many kinds of narrow and broad-leaf weeds are reported in vegetable soybean fields. Several pre- or postemergence herbicides can be used to control weeds.

Introduction

Cultivation of vegetable soybean in Taiwan increased considerably in the late 1980s, and is now the most important crop in terms of export value (Anonymous 1990). Studies on the importance of diseases, insects, and weeds to grain soybean have been well documented, but research on vegetable soybean has been limited, and not at all proportional to the crop's importance. Based on observations and communications with scientists and growers, the key pests of vegetable soybean are essentially the same as those found on grain soybeans. Pesticides registered for grain soybeans (Fei et al. 1990) are also used by farmers to control pests of vegetable soybean. This paper describes the important diseases, insects, and weeds of vegetable soybeans and the methods used to control these pests by the growers in Taiwan.

Diseases

Downy Mildew

Downy mildew (*Peronospora manshurica*) is the most important disease of vegetable soybean in Taiwan (Yeh 1984). The pathogen is seed-borne, but most visible symptoms occur on young leaves as pale green to light yellow spots that enlarge into pale to bright yellow lesions of indefinite size and shape. Lesions later turn grayish-brown to dark-brown with a yellowish-green margin that may finally become entirely brown. On the lower surface of leaves, particularly in moist weather, lesions are covered with tufts of grayish to pale-colored sporangiophores that easily distinguish downy mildew from other foliar diseases (Sinclair and Backman 1989). Pod and seed infection may occur without external symptoms. Heavily infected seeds crack and when germinated, systemically infect seedlings under favorable conditions. Downy mildew is favored by high humidity and temperatures of 20-22°C (Sinclair and Backman 1989). The weather conditions in the spring and fall plantings in Taiwan favor the development of this disease. Primary inoculum comes from the overseasoning of oospores in diseased leaves and/or on infected seed. Dissemination of the pathogen in the field is mainly due to the sporangiospores carried by air currents. Heavily infected plants have reduced photosynthetic activity, and the yield and quality of vegetable soybeans may be affected depending on the severity and the time of infection. With the exception of KS No. 1, all vegetable soybean varieties grown in Taiwan are susceptible. There are specific genes for resistance in grain soybeans although they are not very effective in controlling the disease because there are numerous races of the pathogen.

Rust

Soybean rust (*Phakopsora pachyrhizi*) is an endemic foliar disease of soybeans in Taiwan (Yeh 1981, 1984). The most common symptom is tan to dark-brown or reddish-brown lesions with one to many erumpent, globose, ostiolate uredia. Lesions initially are small, water-soaked, and turning from gray to tan or brown as they increase in size. Lesions appear on petioles, pods, and stems but are most abundant on leaves, particularly on the abaxial surface. The number of uredia per lesion increases with lesion age. Uredospores are exuded through the central pore in the uredium (Yeh 1981; Sinclair and Backman 1989).

Although soybean rust is an endemic disease in Taiwan, it is much more evident on plants after the initial flowering stage. The effect of rust on the yield of vegetable soybean may be much less than that on grain soybean since vegetable soybean is harvested before plant maturity. However, the quality of seeds (especially the size) may be affected due to the decrease in photosynthetic activity.

Primary inoculum comes from soybean plants and/or other leguminous hosts that are infected. Uredospores are wind-blown and produced abundantly on infected tissue. Physiologic races of *P. pachyrhizi* have been identified on grain soybean (Yeh 1983), but there have been no similar studies on vegetable soybean and there are no known cultivars that have resistance.

Rhizoctonia

Rhizoctonia causes pre- and postemergence damping-off, and occasionally the fungus causes aerial blight in localized areas in the field. This disease is much less of a threat to vegetable soybean production than rust or downy mildew.

Preemergence damping-off occurs immediately after the plumule emerges from the seeds. The sprouted seed is decayed and killed by the fungus. Postemergence damping-off occurs a few days after emergence. Lesions appear at the base of the seedling stem and on roots just below the soil line. Lesions enlarge and are often sunken causing girdling of the stem (Sinclair and Backman 1989).

Aerial blight appears on leaves, stems, and pods beginning on the lower or middle parts of the plant and progresses upward as the disease develops. Infected leaves are water-soaked at first, and turn greenish- to reddish-brown before becoming tan, brown, or black. Lesions may be small or may blight the entire leaf.

Rhizoctonia solani is the causal organism of damping-off and aerial blight on soybeans. Damping-off occurs early in the spring planting when the weather is cool and wet, and occurs more frequently when soil is poorly drained. Good soil drainage is recommended for the control of damping-off. Severe seedling infection causes a reduction in stands and thus lowers yields. For control, treatment of seeds with a fungicide is necessary before planting as is treatment of seeds planted to replace the dead seedlings.

Aerial blight is observed later in the spring during pod development when weather conditions are warm and humid. Dead patches of plants often occur scattered in spots throughout the field. No special action has been taken to control this disease.

Vegetable soybeans are prone to infection by pod- and seed-infecting fungi especially during high humidity and rainfall. The most common pathogens found on pods are *Phomopsis* spp. and *Colletotrichum* spp. Production of vegetable soybean seeds can be severely limited if the pods are maturing during the rainy season and are not protected with fungicides. In some regions, seed production of vegetable soybeans could be a limiting factor.

Control

Vegetable soybean cultivars grown in Taiwan are not resistant to the major diseases. Farmers often spray fungicides to control diseases just prior to harvest to reduce the occurrence of pod infection fungi. Low toxicity fungicides such as mancozeb, maneb, and zineb are used to control downy mildew and rust. Other fungicides such as oxycarboxin, triforine, and triclopyr are also registered for control of rust (Fei et al. 1990). Use of clean and/or fungicide-treated seeds may also reduce the spread of downy mildew in the field (Sinclair and Backman 1989).

Insect Pests

Soybean in Taiwan is attacked by a large number of insect pests from shortly after germination through harvest. Chronologically, these pests are: stem feeders, leaf feeders and pod feeders. Each category consists of several insects, some of which are endemic; others cause minor damage.

Stem feeders

Among four agromyzid flies, commonly called 'beanflies,' *Melanagromyza sojae* (Zehntner) is most important in Taiwan. Three other species, *M. dolichostigma* de Meijere, *Ophiomyia phaseoli* (Tryon) and *O. centrosematis* (de Meijere) do occur in Taiwan but their damage to soybean is not significant. *O. phaseoli*, normally a stem feeder in other legumes and soybean in Indonesia, feeds in the petioles of older soybean plants in Taiwan. *O. centrosematis* feeds in cortex just underneath the epidermis of young soybean plants and *M. dolichostigma* is occasionally found girdling tips of 6-8-week-old soybean plants (Talekar and Chen 1986).

M. sojae adults lay eggs in unifoliate and first trifoliate leaves on the underside in the mesophyl tissue. A single adult lays an average of 171 eggs (Wang 1979). The larva hatches in 2-3 days and bores into the nearest vein and continues feeding through the petiole into the stem. In the stem, the larva feeds in the pith boring down to the root until it is fully grown. Before pupation in the pith, the larva gnaws an exit hole in the epidermis to assist in the emergence of the adult. As a result of insect feeding, plant growth is adversely affected and the damaged plant is weakened (Talekar 1989) which can result in up to 30% reduction in yield (AVRDC 1981). In Taiwan, this insect is serious in soybean planted in the autumn season only.

Leaf feeders

Several lepidopterous and coleopterous insects damage soybean in Taiwan. The important defoliators are: *Spodoptera exigua* (Heubner), *S. litura* (F.), *Hedylepta indicata* (F.), *Porthesia taiwana* Shiraki, *Anomala cupripes* Hope and *A. expansa* Bates. Adults of *S. exigua*, *S. litura*, *H. indicata* and *P. taiwana* lay eggs on the leaves and larvae devour the foliage. *S. exigua*, *S. litura* and *P. taiwana* infest soybean in spring and summer; *H. indicata* occurs mainly in autumn. Adults of both *Anomala* species lay eggs in soil and larvae feed on the debris or roots of such economically important crops as sugarcane. Adult beetles feed on soybean foliage from May through October. Defoliators reduce yield indirectly by weakening the plant due to the loss of foliage. The extent of yield loss depends on the level of defoliation and the growth stage of the soybean plant when the defoliation takes place. In Taiwan mid-reproductive stages, R_3 to R_5, are especially sensitive to defoliation. A 50% defoliation at any of the three stages reduces soybean yield significantly (Talekar and Lee 1988).

Pod feeders

Hemipteran stink bugs and lepidopterous pod borers are key pod feeders in Taiwan and throughout Southeast Asia.

Stink bugs. Major stink bugs infesting soybean in Taiwan are *Nezara viridula* (L.), *Riptortus clavatus* (Thunberg) and *Piezodorus hybneri* (Gmelin). Among the three, *R. clavatus* is more important followed by *N. viridula. P. hybneri* occurs only occasionally. Stink bugs pierce the pod pericarp and suck the juice from the developing seeds. As a result, both the yield and quality of soybean are reduced. In certain cases, these insects transmit microorganisms that reduce further the quality and viability of the seeds.

R. clavatus is a polyphagous insect that feeds on seeds from about 30 crop species (Kobayashi 1976). Adult females lay eggs singly on foliage, stems and pods of soybean plants. A female lays 55-90 eggs in her lifetime. The eggs hatch in about 6 days; the nymphal period lasts 16-23 days during which the insect passes through five instars. All nymphal instars and adults feed on developing soybean seeds. In Taiwan this insect damages soybean mainly in summer.

Podborer. Lima bean podborer, *Etiella zinckenella* (Treitschke) is the only podborer species that attacks soybean and several other legumes in Taiwan. The white oval eggs are laid singly or in batches of 2-12 on young pods, calyx or leaf stalks. A single female lays 60-200 eggs (Kobayashi 1976). Incubation lasts 3-16 days, depending upon temperature. Soon after hatching the first instar larvae bore through the pod pericarp and begin feeding on developing seeds. A number of larvae can enter the pod but only one or two survive. Usually one seed provides enough food for a single larva for 20 days' of feeding, by which time the caterpillar leaves the pod and pupates in soil. Pod damage by this species is recognizable even when the larva is absent. Large pods are marked with a brown spot where the larva has entered. As the larva within the pod develops, it causes the buildup of feces. This results in soft rotten patches on the pod. Seeds are partially or entirely eaten, and considerable frass and silk are present. A large hole is evident where the larva has escaped to pupate in the soil. The pest is present in Taiwan practically year-round but its damage is more serious in the dry season during which up to 30% of pods can be damaged. This insect could be a potentially very important pest of vegetable soybean.

Mites, thrips and aphids are sporadic pests of soybean during the cool dry season. Infestation of mites and thrips in Taiwan is induced mainly by excessive use of chemical insecticides which kill predators and parasites of these pests. These pests rarely cause economic damage to soybean in Taiwan.

Control of insect pests

At present, application of insecticides is the only control measure used by the farmers in Taiwan to combat insect pests of soybean. Insecticide use is widespread and some insects like beanflies and lepidopterous defoliators show signs of insecticide resistance. At the same time the potential exists for the use of other methods such as host-plant resistance, sex pheromones, biological control and cultural control measures. Integration of these methods with judicious use of selective insecticides will go a long way toward sustainable control of soybean insect pests in Taiwan.

Beanflies are important only for up to 4 weeks after soybean germination. Any insecticide used to combat these pests should be confined to this period only. Weekly application of chemicals like monocrotophos, dimethoate, omethoate, cyromazine and fungicide pyrazophos gives satisfactory control. The first four chemicals are highly toxic to parasites, a large number of which exist in Taiwan

(Talekar 1990). Cyromazine and pyrazophos are relatively safer to parasites. Selective use of these chemicals will assure survival of parasites and their role in agromyzid control, which in turn will reduce the need for additional insecticide use. Although no varieties with resistance to *M. sojae* have been bred, the potential exists for the development of tolerant cultivars. Plant breeders need to breed for high yield, set yield targets and make selections for high yield by planting the progeny without any insecticide protection in autumn when *M. sojae* infests 100% of soybean plants.

Four soybean accessions, PI 171444, PI 171451, PI 227687 and PI 229358, show levels of resistance to a wide range of defoliators including those that occur in Taiwan (Talekar et al. 1988). None of the accessions is resistant to all insects. It is, therefore, necessary to use all accessions in breeding multiple pest-resistant soybean cultivars. Sex pheromones have already been developed for S. *litura* and S. *exigua*. In addition, large numbers of predators and parasites attack larvae of these two polyphagous pests when chemical insecticides are not used. Use of selective insecticides such as *Bacillus thuringiensis* (Berliner) specifically kill these and other caterpillar pests without harming their natural enemies. Beetle species such as *A. cupripes* and *A. expansa* can be controlled easily by the use of a trap cultivar that produces excessive foliage (Talekar and Nurdin 1991). It is possible to integrate these control measures to develop a sustainable IPM program for all leaf feeders.

Several factors including weather and natural enemies regulate population of stink bugs. Kiritani and Hokyo (1962) showed that more than 94% of *N. viridula* die before becoming adult. A large number of predators and parasites contribute to the reduction in the population of stink bugs (Talekar 1987). Indiscriminate use of chemical insecticides, however, limits the usefulness of these beneficial organisms. One soybean accession, PI 227687, shows resistance to all three stink bug species that infest soybean in Taiwan (AVRDC 1984). Breeding of stink bug resistant cultivars will reduce the need for insecticides and will allow full participation of natural enemies in the control of stink bugs on a sustainable basis.

Among all insect pests of soybean, lima bean podborer is the most difficult to control. Because of its concealed feeding habit in green pods, and the fact that the pods at this stage are concealed under leaf canopy, this insect cannot be controlled by the use of conventional insecticides. No varieties with resistance to this pest exist. Soybean with smaller seeds are always less damaged than those with larger seeds. However, this phenomenon presents distinct disadvantages, particularly for vegetable soybean where only large-seeded cultivars are preferred. Recently one soybean accession, PI 227687, has shown consistent resistance to lima bean podborer (AVRDC 1990a). Although this accession has small seeds, its resistance is due to antibiosis (AVRDC 1990b) rather than small seed size as such. This presents an opportunity to breed a podborer-resistant soybean cultivar.

Recently the presence of sex pheromone in lima bean podborer has been demonstrated. The pheromone has four chemical components which are commercially available (Toth et al. 1989). However, the ideal proportion of components that can attract male podborers seems to vary from place to place. Studies are underway at AVRDC to find a suitable mixture for Taiwan. It is possible to integrate the use of resistant cultivar and sex pheromone to control this pest on a sustainable basis, without resorting to the application of toxic chemical insecticides.

Weeds

Weeds reported in the soybean field include barnyard grass (*Echinochloa cyus-galli* var. *formosensis*), goosegrass *(Eleusine indica)*, green amaranth *(Amaranthus viridis)*, purslane *(Portulaca oleracea)*, narrow-leaf alternanthera *(Alternanthera nodiflora)*, short-awn foxtail *(Alopecurus aequalis* var. *amurensis)*, cut leaf ground cherry *(Physalis angulata)*, *Digitaria chinensis*, *D. microbachne* and *Polygonum hydropiper* (Anonymous 1968; Fei et al. 1990).

More than 10 pre- or postemergence herbicides such as alachlor, linuron, etc., are registered for the control of different kinds of weeds in soybean fields (Fei et al. 1990).

Needed Research

Vegetable soybean is the most important crop commodity exported from Taiwan (Anonymous 1990), but studies on plant protection of vegetable soybeans are not proportional to its importance. Information regarding the important diseases, insects, and weeds associated with vegetable soybean production is limited. Surveys of vegetable soybean pests are needed to determine their importance and potential threat to production. Cultivation of resistant cultivars, if available, is the most economic and effective strategy in pest control. Screening of grain soybean germplasm for resistance to key pests has been conducted with the identification of sources of resistance/tolerance (Anonymous 1981, 1982; Athow 1973). Screening of vegetable soybean segregating populations and germplasm for resistance to the key pests is important once the primary pests have been identified in surveys. Since pods of vegetable soybean are harvested before maturity, pesticide use should be minimal and then only in the early growing stage. Pesticides with short residual life are better for the safe production of vegetable soybean. Development of nonchemical control measures such as natural enemies, e. g. parasitoids and predaceous mites (Chiu and Chou 1986, Wang 1984), is very important. Development of an integrated pest management system including the use of clean seed, seed treatment, and cultural practices such as crop rotation and good drainage may help reduce the occurrence of diseases and insects on vegetable soybeans.

References

Anonymous. 1968. Weeds found on cultivated land in Taiwan. Department of Agronomy, National Taiwan University, 444 p.

1990. Taiwan Agricultural Year Book. 1989. Taiwan Provincial Department of Agriculture and Forestry, Chung Hsing Village, Nantou, Taiwan.

Athow, K. L. 1973. Chapter 13, Fungal diseases. *In*: Caldwell, B. E., Howell, R. W., Judd, R. W., and Johnson, H. W. (ed.) Soybeans: Improvement, Production, and Uses. American Society of Agronomy, Inc. Madison, WI, USA, 459-490.

AVRDC. 1981. Progress Report for 1980. Asian Vegetable Research and Development Center, Shanhua, Taiwan, 110 p.

1984. Progress Report for 1982. Asian Vegetable Research and Development Center, Shanhua, Taiwan, 337 p.

1990a.1988 Progress Report, Asian Vegetable Research and Development Center, Shanhua, Taiwan, 414 p.

1990b.1989 Progress Report. Asian Vegetable Research and Development Center, Shanhua, Taiwan, 351 p.

Fei, W. C., Chen, C. F., and Hwang, Y. H. (ed.) 1990. Plant Protection Manual. Taiwan Provincial Department of Agriculture and Forestry, 562 p.

Kiritani, K., and Hokyo, N. 1962. Studies on the life table of the southern green stink bug, *Nezara viridula* L. Jpn. J. Appl. Entomol. Zool., 6, 124-139.

Kobayashi, Y. 1976. Insect pests of soybean in Japan and their control. PANS, 22, 336-349.

Sinclair, J. B., and Backman, P. A. 1989. Compendium of Soybean Diseases. American Phytopathological Society, 3340 Pilot Knob Rd., St. Paul, MN. 55121, USA. 106 p.

Talekar, N. S. 1987. Insects damaging soybean in Asia. *In*: Singh, S. R., Rachie, K.O., and Dashiell, K. E. (ed.), Soybean for the Tropics. London: John Wiley and Sons Limited. p 25-45.

1989. Characteristics of *Melanagromyza sojae* (Diptera: Agromyzidae) damage in soybean. J. Econ. Entomol., 82, 584-588.

1990. Agromyzid flies of food legumes in the tropics. New Delhi: Wiley Eastern. 299 p.

Talekar, N. S., and Chen, B. S. 1986. The beanfly pest complex of tropical soybean. 257-271. *In*: Shanmugasundaram, S., Sulzberger, E.W., and McLean, B.T.(ed.), Soybean in Tropical and Subtropical Cropping Systems.

Proceedings of a symposium, Tsukuba, Japan, 26 September–1 October 1983. Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Talekar, N. S., and Lee, H. R. 1988. Response of soybean to foliage loss in Taiwan. J. Econ. Entomol., 81, 1363-1368.

Talekar, N. S., Lee, H. R., and Suharsono. 1988. Resistance of soybean to four defoliator species in Taiwan. J. Econ. Entomol., 81, 1469-1473.

Talekar, N. S., and Nurdin, F. 1991. Management of *Anomala cupripes* and *A. expansa* in soybean by using a trap cultivar. Trop. Pest Mgnt. (in press).

Toth, M., Lofstedt, C., Hansson, B. S., Szoes and Farag, A. I. 1989. Identification of four components from the female sex pheromone of the lima-bean podborer, *Etiella zinckenella*. Entomol. Exp. Appl., 51, 107-112.

Wang, C. L. 1979. Occurrence and life history of *Melanagromyza sojae* on soybean. J. Agric. Res. China, 28, 217-223.

Yeh, C. C. 1981. Rust and purple seed stain of soybeans. Ph.D. thesis, University of Illinois, Urbana, Ill. 103 p.

1983. Physiologic races of *Phakopsora pachyrhizi* in Taiwan. Jour. Agr. Res. China, 32,69-74.

1984. Major diseases of leguminous crops and their control. *In*: Chen, C. N., Li, G. C., and Fei, W. C. (ed.) Plant Protection in the Republic of China, 1954-1984, 103-107. The Plant Protection Society of the Republic of China, Taichung, Taiwan, ROC, 347 p.

Quality Requirement and Improvement of Vegetable Soybean

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Abstract

Vegetable soybean ("Edamame") is very popular in Japan because of its characteristic flavor, sweetness and body taste (umami in Japanese). Quality requirements of vegetable soybean are grouped into five major categories including appearance, taste, flavor, texture and nutritional value.The pod color is important, and bright-green is most desirable. Yellowing of the pods reflects freshness decline and degradation of ascorbic acid. Sensory evaluation of stored vegetable soybean showed that the taste of the seeds is mainly determined by sucrose, glutamic acid and alanine. Saponins, which give a bitter taste, are found in the seed and are rich in hypocotyl. Flavor and texture of boiled vegetable soybean are also highly correlated to their sensory scores. The boiled soybean contain a characteristic sweet flower-like and beany flavor. Vegetable soybean is as nutritious as other soybean products, and a good source of tocopherols, dietary fibers and ascorbic acid. Trypsin inhibitors and antinutritional factors remain in boiled seeds. Quality improvement of vegetable soybean covers both pre- and postharvest considerations. Seed maturity, growth environment and cultural practices affect the quality of soybean seeds at harvest. Studies covering pre- and postharvest procedures made it possible to retain freshness, sucrose and free amino acid levels. Some studies have been done related to genetic control of sucrose and free amino acid levels in legumes, which may lead to quality improvement of vegetable soybean in the future. Physiological approaches to control sucrose and free amino acids are now being studied in soybean seeds.

Introduction

Vegetable soybean is rich in protein, vitamins A, C and E, and its characteristic flavor is widely appreciated in Japan. Eating boiled vegetable soybean ("edamame") seed has a 400-year history in Japan. Vegetable soybean and beer is a favored combination in restaurants or at home in the summer. The vegetable soybean is boiled in salt water and served as hot pods; only the seeds are eaten. Vegetable soybean is processed as "Zunda-mochi", made into a paste. Zunda-mochi is famous in Tohoku, Japan, but production is limited. Most immature vegetable soybean is consumed in Japan as "edamame" (110,000 t in 1988).

Quality Requirements and Evaluation

Vegetable soybean is recognized as a "tidbit" rather than a basic food. Although there are few available data on consumer preferences, vegetable soybean is widely accepted because of its characteristic volatile flavor, sweetness and body taste. In Japanese, body taste is called "umami" (Torri 1987). Yamaguchi et al. (1971) showed that umami consists of various flavor amino acids and nucleotides. Major quality requirements of vegetable soybean in terms of palatability are appearance, taste, flavor and texture (properties of structure). The pods should be bright-green and a good shape with spotless surface to fetch a good price at the wholesale and retail market. The primary requirement is good pod appearance. The surface condition indicates the amounts of chemical components in the seed (e.g. yellowing reflects freshness decline and degradation of sugars, free amino acids and ascorbic acid—Iwata and Shirahata 1979; Akimoto and Kuroda 1981). The usefulness of pod color evaluation as an indicator of seed freshness during storage is shown in Fig. 1.

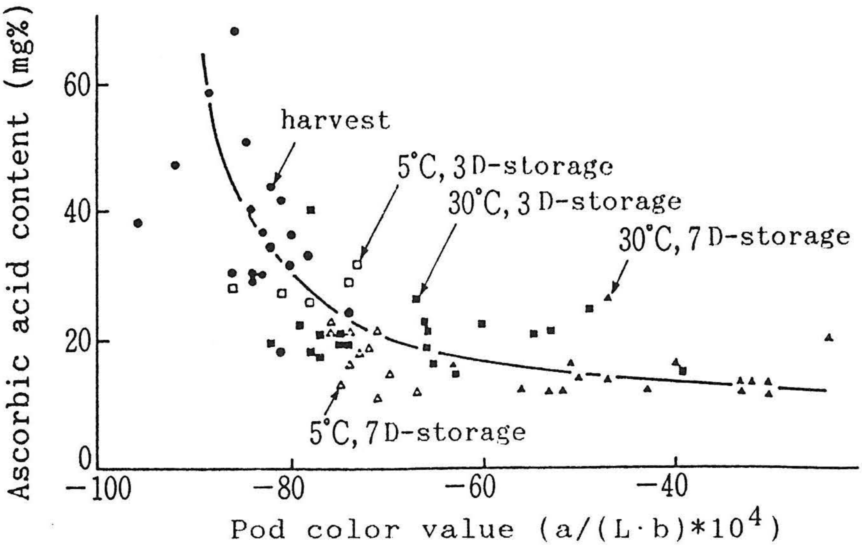

Fig. 1. Relationship between pod color (a/(L×b)×10^4) and ascorbic acid content of seed during the storage of vegetable soybean (Akimoto and Kuroda 1981).

There are many taste-related substances in soybean seed, such as sugars, amino acids, organic acids, inorganic salts, flavonoids and saponins. Preliminary results show that younger panelists prefer higher sucrose types of vegetable soybean rather than common sweet ones (Konovsky 1990). Storage experiments of vegetable soybean pod at room temperature showed that sensory panelists could perceive quality differences in freshly harvested soybeans and those harvested 10 hours previously (Fig. 2) (Masuda et al. 1988). The high correlations between contents of chemical components (Fig. 3) and sensory scores of boiled vegetable soybean are shown in Table 1. Major components related to taste are sucrose, glutamic acid and alanine. Further studies are required to clarify the contribution of minor components to organoleptic quality.

Table 1. Correlations between sensory panel scores (Fig. 2) and sucrose and glucose (Fig. 3), glutamic acid and alanine contents (Fig. 3-C) in vegetable soybean seeds held at different periods at 26°C.

	Correlation coefficient (g)[a]			
Variable	Sucrose	Glucose	Glutamic acid	Alanine
Sweetness	0.76	0.57	0.72	0.50
Taste	0.86	0.56	0.79	0.66
Overall	0.88	0.59	0.82	0.65

[a] n = 8

Unacceptable features include bitter, astringent and metallic off-flavors of soybean seed, and so-called dry-mouth feeling (Table 2) (Okubo 1988).

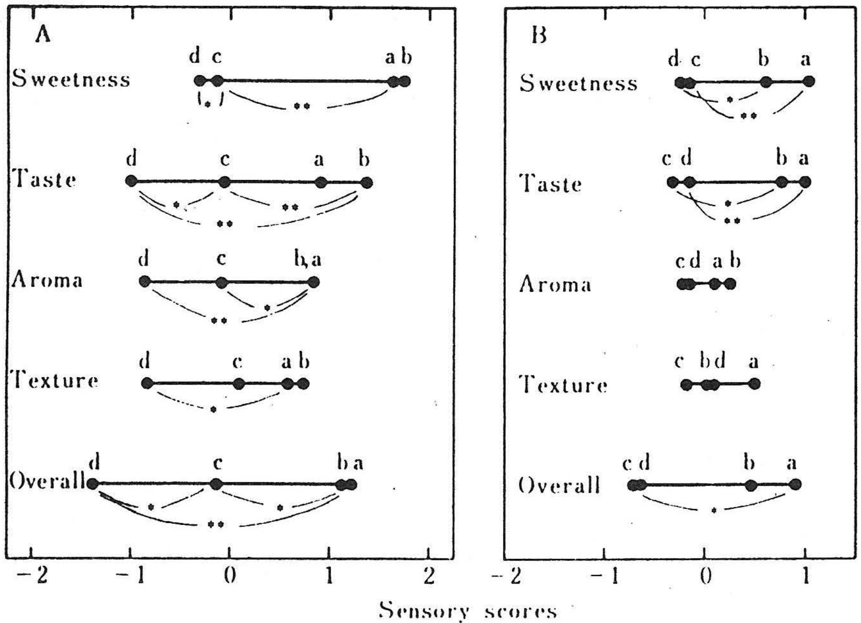

Fig. 2. Changes in sensory panel scores of vegetable soybean seeds held at 26°C for different periods. (A): harvested 20 Aug. 1985. Held for 30 min (a), 8 hours (b), 24 hours (c) and 48 hours (d); (B): harvested 22 Aug. 1985. Held for 40 min (a), 3 hours (b), 10 hours (c) and 24 hours (d). After frozen storage for 2 weeks, vegetable soybean boiled in water were evaluated using a scoring method (an 11-point hedonic scale) by 20 judges in (A) or 28 judges in (B). *,**: Significant difference at 5% or 1% level of probability.

Table 2. Sensory properties of undesirable components of soybean (Okubo 1988).

Components	Properties	Sources
Phenolic acids	Sour, bitter, astringent flavor	defatted seed
Oxidized phosphatidylcholine	bitter	defatted seed
Oxidized fatty acid	bitter	oxidized oil
Hydrophobic peptide	bitter	fermented products
Isoflavin	objectionable taste, bitter, astringent, Weak phenol-like taste	defatted seed
Daidzin	bitter, astgringent	whole seed
Genistin	bitter, astringent	whole seed
Saponin	bitter	whole seed
A group saponin	bitter, astringent	hypocotyl
B group saponin	bitter, astringent	whole seed
Soyasaponin I	bitter, astringent	dried pea

Saponins and isoflavins are responsible for these off-flavors and their thresholds are organoleptically low (Fig. 4) (Okubo 1988). The higher content of total saponins is observed in the seed hypocotyl fraction than in other seed fractions, ranging from 0.62 to 6.16% (Shiraiwa et al. 1991). The content of saponins in soybean seed varied with the maturity of seed, and was more highly dependent on the variety than on the cultivation year. No information on dry-mouth feeling effects in boiled vegetable

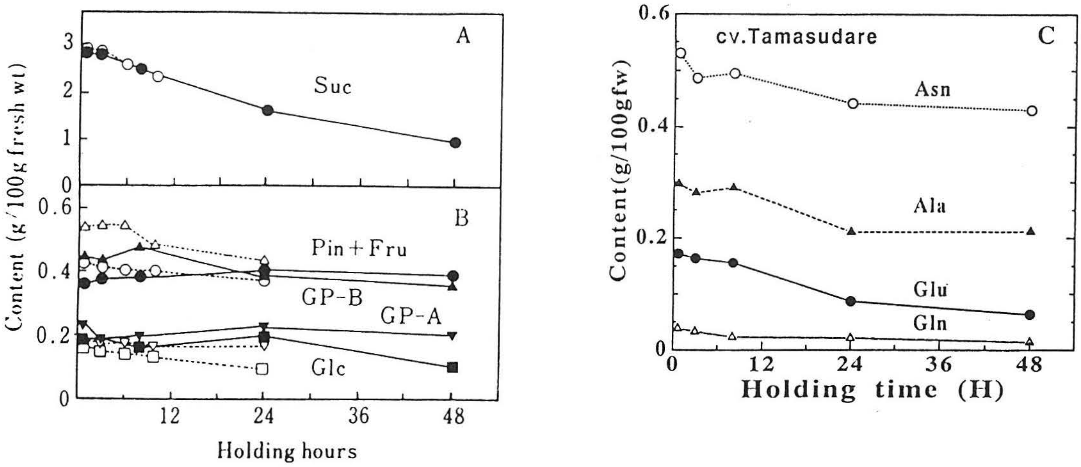

Fig. 3. Changes in sugar content in vegetable soybean seeds held at 26°C. (A): sucrose; (B): pinitol + fructose (●, ○), glucose (■, □), galactopinitol A (▼, ▽) and galactopinitol B(▲, △); *closed symbols*: harvested on 20 Aug. 1985; *open symbols*: harvested on 22 Aug. 1985. Galactopinitol contents were calculated on the assumption that their sensitivity to an RI detector were the same as that of maltose.

C. Changes in free amino acid content of vegetable soybean seeds held at 26°C, harvested 20 Aug. 1985 (Masuda et al. 1988).

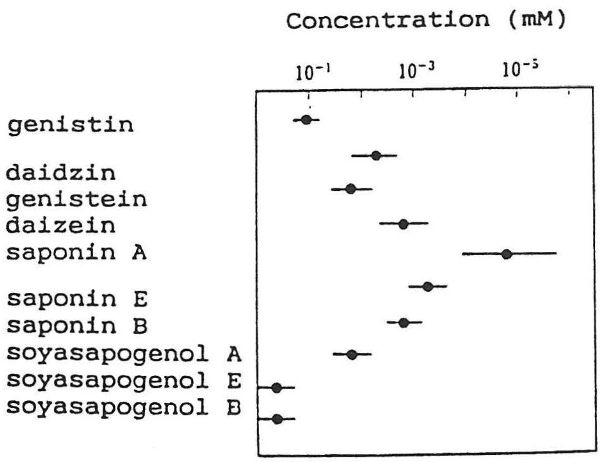

Fig. 4. Stimulus threshold values of glycosides in soybean seed (Okubo 1988).

soybean is available. Studies on bioactivities of saponins and isoflavins cover a wide range from antifungal to pharmaceutical fields.

Oligosaccharides of soybeans have been generally considered undesirable, because raffinose and stachyose are factors responsible for the flatulence and abdominal discomfort often experienced after ingestion of soybeans. Recently, however, these have been reported to support the growth of bifidobacteria, and to play an important role in health (Nakayama 1987). Oligosaccharides extracted from soybeans are added to beverage products.

Volatile flavor of the boiled vegetable soybean is highly correlated with quality (Fig. 2). Sugawara et al. (1988) investigated the change in flavor components of seeds during pod-filling stage. The GLC and GLC-MS analysis of substances steam-distilled and ether-extracted indicated remarkable differences between immature and mature soybean (Fig. 5). Characteristic, flower-like flavor components of boiled vegetable soybean are *cis*-jasmone, (Z)-3-hexenyl-acetate, linalool and acetophenone. Major components, 1-octen-3-ol, 1-hexanol, hexanal, 1-pentanol, (E)-3-hexen-1-ol, 2-hepta-none and 2-pentylfuran, the beany flavor (Maga 1973) are also detected in vegetable soybean (Sugawara et al. 1988). Boiling gives seeds their characteristic flavor because of heat-induced substances such as furans and ketones, and easy evaporation of volatiles due to rupture of tissue and cells. Cell rupture accompanied by freezing gives undesirable flavor due to lipid peroxides. Popcorn or pandan-like flavor are perceived in Dedacha-mame or Cha-kaori types. The flavor components might be cyclo N-O substances, probably by GLC analysis (Masuda 1989).

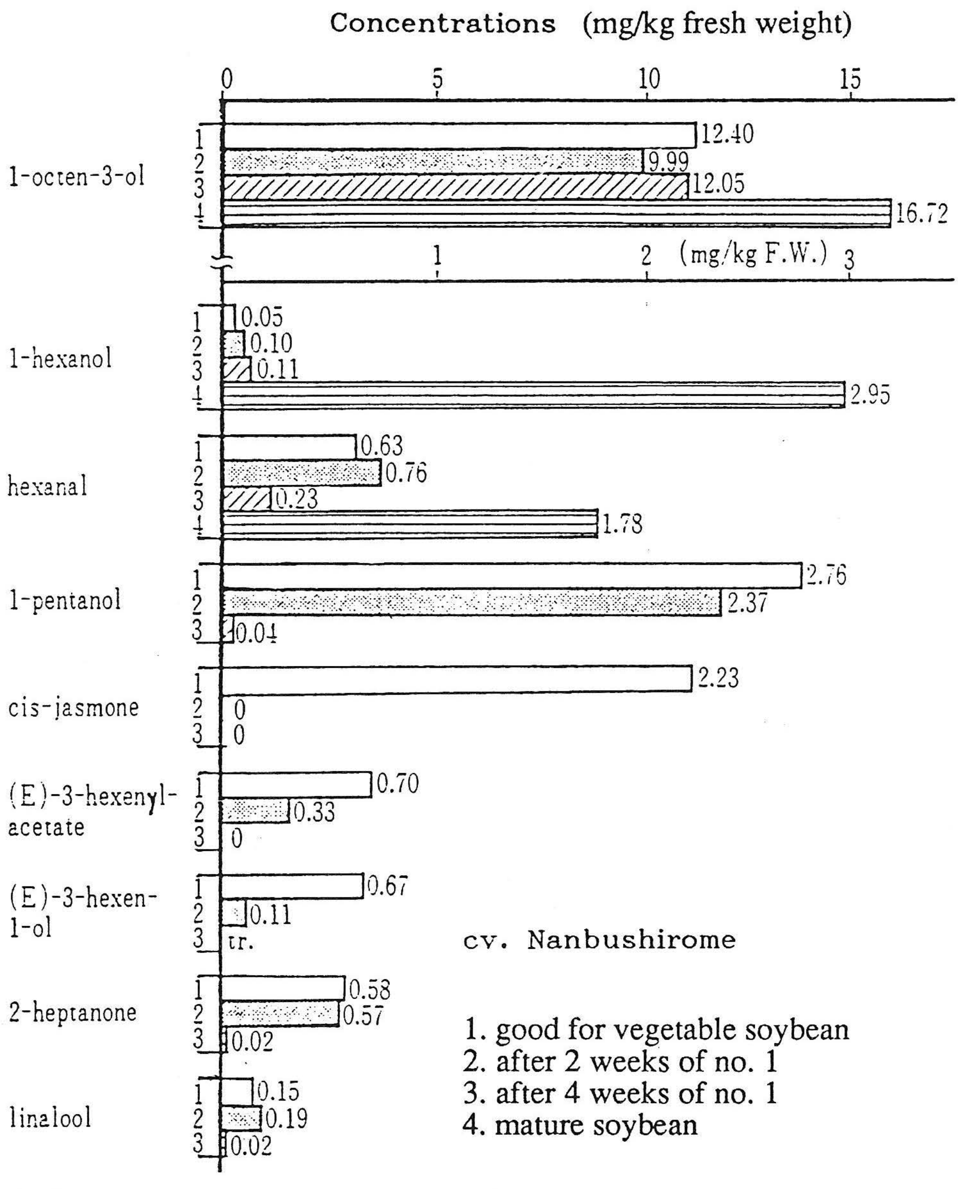

Fig. 5. Changes in levels of characteristic aroma of cooked vegetable soybean seeds during the pod-filling stage (Sugawara et al. 1988).

Table 3. Nutritional content of some soybean and pea products (Standard Tables of Food Composition in Japan; fourth ed., 1982).

Composition	Nattou	Momen tofu	Vegetable soybean	Pea	Green pea
Energy (Kcal/100g)	200	77	582	30	96
Water (g/100g)	59.5	86.8	71.1	90.3	75.7
Protein (g/100g)	16.5	6.8	11.4	2.9	7.3
Lipid (g/100g)	10.0	5.0	6.6	0.1	0.2
Nonfibrous carbohydrates (g/100g)	9.8	0.8	7.4	5.4	13.0
Fiber (g/100g)	2.3	0	1.9	0.8	2.9
Dietary fiber* (g/100g)			15.6		6.3
Ash (g/100g)	1.9	0.6	1.6	0.5	0.9
Calcium (mg/100g)	90	120	70	55	28
Phosphorus (mg/100g)	190	85	140	60	70
Iron (mg/100g)	3.3	1.4	1.7	0.8	1.9
Sodium (mg/100g)	2	3	1	1	3
Potassium (mg/100g)	660	85	140	60	70
Carotene (mg/100g)	0	0	100	620	360
Vitamin B1 (mg/100g)	0.07	0.07	0.27	0.12	0.25
Vitamin B2 (mg/100g)	0.56	0.03	0.14	0.10	0.12
Niacin (mg/100g)	1.1	0.1	1.0	0.6	1.9
Ascorbic acid (mg/100g)	0	0	27	34	18

*Innan (1985).

Texture also contributes to vegetable soybean quality. The soybean with hard seeds give low scores. Until growth reaches middle pod-filling stage, the seeds become harder with maturity. Vegetable soybean variety "Tanba-guro" has a large seed size with moderate texture compared to normal vegetable soybean (Masuda et al. 1988).

Vegetable soybean as well as other soybean products has good nutritional values, with high levels of vitamin C and dietary fiber (Table 3). Galactomannans are found in the seed coat. The compositional and quantitative changes in fatty acid (Table 4) and tocopherols (TC) (Table 5) have also been reported (Kajimoto et al. 1982). The ratio of linoleic acid in total lipids and triacylglycerol increased with maturity, but the ratios of linoleic acid and palmitic acid decreased. The main TC, a-, g- and, d-TC in seed lipid fractions and total TC showed an increase with maturity.

Soybean seed has antinutritional substances, such as protease inhibitors. One-third of activity of trypsin inhibitor (TI) remains in vegetable soybean seed after boiling for 5 min (Tanimura et al. 1980). TI activity was not observed during 116 days of cultivation and increased with the growth of seeds (Table 6).

Taste Related Substances During Pre- and Postharvest Periods

Environmental factors, such as location, season and weather (light intensity, water content) greatly affect the quality of vegetable soybean.

Vegetable soybean is harvested at about 33-38 days after flowering (DAF) depending on its pod color and thickness. Tanusi (1972) observed that sucrose level increased during early developing stages, but

Table 4. Changes in fatty acid composition of total lipids, triacylglycerols and compound lipids in soybean seed during maturation.

Days after flowering:	25			40			45			50			75		
Lipid Groups:	Total Lipid	TG	CL	Total Lipid	TG	CL	Total lipid	TG	CL	Total Lipid	TG	CL	Total Lipid	TG	CL
Fatty acid (%)															
14:0	0.9	trace	2.4	-	-	-	-	-	1.8	-	-	1.4	-	-	2.5
16:0	16.3	15.8	23.5	11.1	11.3	15.8	8.7	9.3	16.0	9.2	12.5	29.2	10.0	9.3	21.3
18:0	3.5	3.1	6.2	2.3	1.6	3.1	1.9	1.5	3.8	1.8	0.7	3.2	2.3	2.3	3.0
18:1	35.8	42.5	34.5	51.0	51.0	46.8	57.2	61.3	46.1	42.5	52.9	12.2	21.9	25.2	4.8
18.2	32.1	31.6	21.2	29.4	31.9	23.6	27.6	24.4	25.1	41.1	31.6	45.6	58.2	54.4	61.8
18.3	11.4	7.0	12.0	6.2	4.3	9.1	4.6	3.5	6.2	5.5	2.3	8.2	7.5	8.8	6.0
Total USFA	79.3	31.1	67.7	86.6	87.2	79.5	89.4	89.2	77.4	89.1	86.8	66.0	87.6	88.4	72.6

TG: Triacylglycerol, CL: Compound lipid, USFA: Unsaturated fatty acid.

Table 5. Changes in tocopherol content in total lipids and seed during maturation.

Days after flowering:		25	40	45	50	75
	α	32	44	85	145	109
Tocopherol content	β	trace	2	6	46	62
(μg/g lipid)	γ	1,038	1,124	1,186	918	1,109
	δ	148	306	340	336	402
Total		1,212	1,476	1,617	1,445	1,682
Tocopherol contents (μg/seed)		6	12	33	45	83

Table 6. Changes of water content, crude protein, total trypsin inhibitor activity and specific activity during soybean cultivation (seed length 1.2-1.4 cm).

No.	Cultivation duration (days)	Water content (%)	Crude protein (%)	Total trypsin inhibitor activity (mg/g of fresh weight)	Specific activity[c]
A	123	82.55	8.40 (48.14)[a]	9.74 (55.82)[b]	116
B	130	76.45	9.51 (40.34)	15.74 (66.84)	165
C	137	72.07	10.69 (38.27)	17.92 (64.16)	168
D	144	69.43	11.80 (38.60)	17.49 (57.21)	148
E	152	65.56	13.35 (38.76)	17.70 (51.39)	133
F	159	47.06	15.01 (28.35)	18.47 (34.88)	123
G	165	15.13	32.390 (38.06)	38.18 (44.98)	118

[a] Number in parentheses is percent dry matter.
[b] Number in parentheses is mg/g of dry weight.
[c] Total trypsin inhibitor activity ($\times 10^3$ µg/g)/crude protein (g).

35 DAF the level tended to decline. Furthermore, Masuda (1989; and unpublished data) reported the diurnal changes in sucrose and free amino acid levels of seed at 33-36 DAF (Fig. 6-7). The sensory scores of the boiled vegetable soybean, harvested at different times of the day, showed no significant differences in sweetness, texture and overall scores except flavor. Both harvest time in terms of number of days after planting and harvesting hour in the day affect the quality of vegetable soybean.

After harvest, the shorter the time before cooling and blanching, the better the quality (Fig. 3). Development of time-saving procedures on a large scale before cooling or blanching is a major concern.

Genetic and Physiological Research on Quality Improvement

A genetic character of variety is a primary determinant of vegetable soybean quality from the pre- and postharvest points of view.

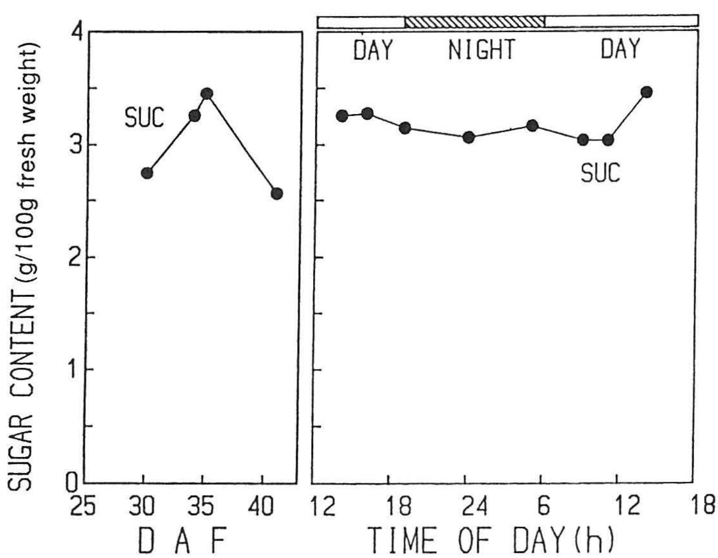

Fig. 6. Changes in sucrose content of vegetable soybean (cv. Tamasudare) seed at mid-pod-filling stage (Masuda 1989).

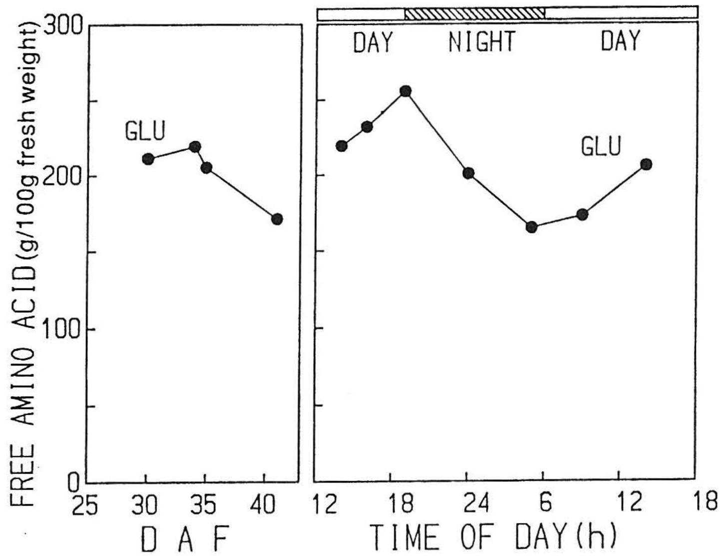

Fig. 7. Changes in glutamic acid content of edamame (cv. Tamasudare) seed at mid-pod-filling stage (Masuda 1989).

Studies on genetic improvements of soybean with regard to undesirable substances have been carried out to exclude lipoxygenase proteins. Genetic alterations produced more nutritious varieties in terms of protein composition, amino acid composition of protein or fatty acid composition of lipid in the cotyledon. Other substances, sucrose or free amino acid, are not yet targets of the breeding program.

Until now, vegetable soybean cultivars have been bred from varieties with emphasis on the green color of immature pods and acceptable taste of seeds, as well as properties related to seed production. It is interesting that sucrose and free amino acids increase at the green pod stage. The analysis of components of vegetable soybean varieties at green pod stage indicated that they have a higher sucrose content (not less than 2.5% fresh weight) than normal soybean cultivars (cv. Enrei, Harosoy 63) (Masuda et al. unpublished data). There are high-sugar cultivars among old soybean varieties, but their level of total sugars does not exceed 6% on a fresh weight basis (Table 7) (Katou et al. 1982). Mutation breeding rather than crossbreeding between higher-type varieties might be successfully introduced to vegetable soybean, as with sweet corn.

Table 7. Content of sugars and free amino acids in vegetable soybean and normal soybean seeds (Katou et al. 1982).

	Sugars		Free amino acids (FW %)	
Cultivar	Harvest	3-day storage	Harvest	3-day storage
Shounai 2	6.21	1.10	1.05	0.43
Shirayama dadacha	5.03	1.20	0.90	0.36
Hirata dadacha	4.72	1.52	0.91	0.31
Murasaki dadacha	5.20	1.31	1.09	0.55
Kinbou dadacha	5.54	2.36	0.92	0.51
Wase siroge	4.27	2.08	0.23	0.19
Oku siroge	4.39	1.84	0.32	0.17
Tohoku 54	4.84	2.77	0.35	0.19
Higan-ao	5.28	2.15	0.92	0.25
Oku dadacha	5.25	1.71	0.72	0.27

Starch content of seeds changes with maturity, and reaches maximum (22%) at the mid-pod-filling stage, and then decreases (0.3%) (Tanusi 1972; Yazdi-Samadi et al. 1977). Miyazaki et al. (1985) reported that Koito-zairai and Tururan-daizu are high starch varieties at maturity. Starch accumulation in mid-pod-filling stage plays a role of a transient reservoir of the carbon supply. Varieties that accumulate high levels of starch at vegetable soybean stage might be changed to high sucrose types, by means of genetic suppression of starch synthesis enzymes (ADP-glucose pyrophosphorylase, branching Q enzyme and sucrose synthase).

Free amino acid level in the seed at the green stage is controlled by the balance between protein synthesis activities and amino acid supplies from different parts of the plant. Remarkable differences are observed in free amino acid level between two types, vegetable soybean and normal-type seeds (Fig. 8) (Masuda, unpublished data). Asparagine and glutamine accumulate in vegetable soybean seeds. No significant differences in glutamic acid level were observed between two types, but the time of maximum level was different. It is suggested (Masuda, unpublished data) that nitrogen assimilation enzymes, asparaginase, glutamine synthetase in inner-layer of seed coat and glutamate synthase in cotyledons play significant roles in regulation of free amino acid "pool" in soybean seed. Altering the free amino acid level, especially glutamate level to improve quality, will be a future target.

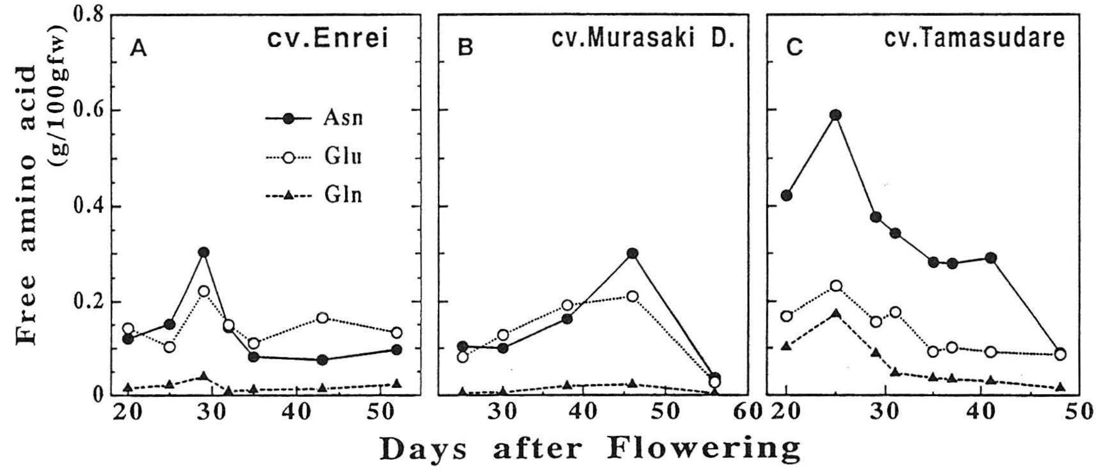

Fig. 8. Changes in free amino acid content of some soybean varieties at mid-pod-filling stage. A: cv. Enrei, B: cv. Murasaki Dadacha; C: cv. Tamasudare.

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References

Akimoto, K., and Kuroda, S. 1981. Quality of green soybeans packaged in perforated PE/PP film. J. Jap. Soc. Hort. Sci., 50, 100-107.

Innan, T. 1984. Dietary fibers contents in some food categories. Syoku No Kagaku, 94, 37-50.

Iwata, T., and Shirahata, K. 1979. Keeping quality of green soybeans. J. Jap. Soc. Hort. Sci., 48, 106-113.

Kajimoto, G., Shibahara, A., and Yamashoji, S. 1982. Changes in the contents and compositions of lipids, fatty acids, tocopherols and sterols in soybean seed during maturation. Journal of Japanese Society of Food and Nutrition, 35, 345-350.

Katou, T., Fukushima, T., and Akazawa, T. 1982. Differences in contents of amino acid, sugars and composition of fatty acids between edamame and normal soybean. J. Jap. Soc. Hort. Sci., 51(suppl. 2).

Konovsky, J. 1990. The relationship of consumer preference to the amino acid and sugar content of edamame. Jap. J. Breed., 40 (supp. 2)

Maga, J.A. 1973. A review of flavor investigations associated with the soy products, raw soybeans, defatted flakes and flours, and isolates, J. Agric. Food Chem., 21, 864-868.

Masuda, R. 1989. Freezing of Vegetables (16) Edamame. Refrigeration, 64, 359-376.

Masuda, R., Hashizume, K., and Kaneko, K. 1988. Effect of holding time before freezing on the constituents and the flavor of frozen green soybeans (edamame). Nippon Shokuhin Kogyo Gakkaishi, 35, 763-770.

Masuda, R., Kamati, K., Hayakawa, T., Yamaya, T., and Ojima, K. 1991. Changes in levels of enzymes related to glutamate metabolism in soybean testa and cotyledons during the pod filling stages. (in preparation)

Miyazaki, S., Yagasaki, K., and Yasui, T. 1985. The rapid determination of starch in soybean seeds with iodine-starch staining. Jap. J. Crop. Sci., 54, 177-178.

Nakayama, M. 1987. Technical Report of New Sweetener. Masai, T. (ed.) Daiichi International Co. Ltd., 151–166.

Okubo, K. 1988. Dry mouth feel, undesirable components of soybean and behavior of the components on soybean food processing. Nippon Shokuhin Kogyo Gakkaishi, 35, 866-874.

Shiraiwa, M., Harada, K., and Okubo, K. 1991. Composition and content of saponins in soybean seed according to variety, cultivation year and maturity. Agric. Biol. Chem., 55, 323-331.

Sugawara. E., Ito, T., Odagiri, T., Kubota, K., Kobayashi, A. 1988. Changes in aroma components of green soybeans with maturity. Nippon Nogeikagaku Kaishi, 62, 149-155.

Tanimura, W., Kamoi, I., and Obara, T. 1980. Distribution of trypsin inhibitors in green soybean (edamame) during cultivation. Nippon Shokuhin Kogyo Gakkaishi, 27, 245-251.

Tanusi, S. 1972. Changes of carbohydrate contents of the soybean seed (cotyledon, hull and hypocotyl) during growth. J. Jap. Soc. Food Nutri., 25, 89-93.

Torii, K. 1987. Umami; A basic taste. Kawamura, Y., and Kare, M. R. (ed.) New York: Marcel Dekker.

Yamaguchi, S., Yoshikawa, T., Ikeda, S., and Ninomiya, T. 1971. Measurement of the relative taste intensity of some L-amino acids and 5'-nucleotides. J. Food Sci., 36, 846-849.

Yazdi-Samadi, B., Rinne, R. W., and Seif, R. D. 1977. Components of developing soybean seeds: oil, protein, sugars, starch, organic acids and amino acids. Agron. J., 69, 481-486.

Research on Vegetable Soybean Quality in Taiwan

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Abstract

Taiwan has no full-spectrum grading system of its own for the domestic soybean market. Quality research has been limited and focused mostly on the processing industry. Although a grading system for appearance has been developed, nutrient content and eating quality have not been covered. Application of near infrared reflectance spectroscopy (NIRS) was used to determine the sweetness, hardness and taste components of eating quality, and gas chromatography was used to determine vegetable soybean flavor, the fourth component. Nevertheless, because of the complexity of analyzing overall quality, panel tests are still the most frequently used evaluation methods.

Introduction

Immature pods of grain soybean have long been consumed as a fresh vegetable by Chinese people. Larger seed size with sweet taste is generally preferred. There is, however, no grading system established for the marketing of vegetable soybeans. The grading system presently used by processors was adopted from Japan (Liu and Shanmugasundaram 1984) and is not commonly used in the Taiwan domestic market.

The amount of effort addressed to quality research of vegetable soybean in Taiwan has been quite limited, mostly aimed at the processing industry. Studies have been conducted to estimate the required blanching time for vegetable soybean. It was found that the blanching time needed to inactivate lipoxygenase is shorter than that for peroxidase of the vegetable soybean (Williams et al. 1986). Studies on the rates of postharvest degradation under different temperatures were also conducted. Refrigerated storage of vegetable soybean before processing is recommended (Masuda 1989). This report summarizes recent studies carried out at the Asian Vegetable Research and Development Center (AVRDC). Applications of near infrared reflectance spectroscopy (NIRS) for quality evaluations are emphasized.

Quality of Vegetable Soybean

The parameters used to evaluate the quality of vegetable soybeans include appearance, eating quality and nutrient content. A grading system for appearance has been developed based on pod size, number of seeds per pod, pod color and the degree of pest damage. Hence appearance becomes an essential criterion in quality evaluation for vegetable soybean processing. However, there are no specifications established for the eating quality and nutrient content in Taiwan. These two qualities often vary with the preference of consumers, and thus the evaluations of these two properties can only provide descriptive information rather than grading parameters at this time.

Analysis of the nutrient content has shown that vegetable soybean is an excellent source of thiamine, and also a good source of protein, riboflavin and iron (Shanmugasundaram et al. 1989). It would be important to evaluate the nutrient content in the new varieties to be released for commercial production

The general practice at AVRDC is that the content of major nutrients in the new lines should be over 90% of check varieties.

Panel tests have shown that the eating quality of vegetable soybean consists of its sweetness, flavor, texture and taste. The contributions of each component to overall eating quality are almost the same. Thus evaluation methods for all four parameters are required in order to provide a more complete description on quality of vegetable soybean.

Sweetness of Vegetable Soybean

The carbohydrate patterns of vegetable soybean are different from those of grain soybean (Table 1). Starch, which is low in grain soybean, makes up 10% of the dry weight of vegetable soybean. The oligosaccharide content of vegetable soybean is very low.

Table 1. The carbohydrate patterns of vegetable soybean and grain soybean.

Carbohydrate	Vegetable soybean (mg/g dry wt)	Grain soybean (mg/g dry wt)
Starch	83.20	0.66
Total sugar	110.20	102.40
Sucrose	99.14	62.05
Glucose	13.40	11.18
Fructose	8.95	0.73
Raffinose	0.16	14.85
Stachyose	0.95	25.38
Crude fiber	44.90	52.70

Mean of three varieties: Kaohsiung No. 1, Tzurunoko, and Ryokkoh.

Tsou and Hong (1990) indicated that sucrose, which is the predominant sugar in vegetable soybean, is responsible for its sweetness. Therefore analysis of sucrose content is most important in the evaluation of the sweetness of vegetable soybean (Masuda et al. 1988).

NIRS has been found to be a useful tool in estimating chemical composition of vegetable soybean and other commodities (Tsou et al. 1989). This technique was adopted to analyze individual sugars. The prediction statistics of NIRS method to estimate carbohydrate in vegetable soybeans are given in Table 2. Acceptable predictions on sucrose are obtained by the NIRS method. Accuracy of the estimates on individual oligosaccharides is relatively low due to their lower concentration in vegetable soybean. A better correlation coefficient ($R^2 = 0.87$) and a standard error of prediction (SEP = 1.02) were obtained in the estimation of total oligosaccharides.

Taste of Vegetable Soybean

In addition to sucrose, certain free amino acids are suggested as major contributors to the taste of vegetable soybean. Analysis of amino acid profiles indicated that the free amino acid content is much higher in vegetable soybean than in grain soybean. Free glutamic acid has the highest concentration over other amino acids. This single amino acid consists of 0.43% of the fresh weight of vegetable soybean (Tsou and Hong 1990). NIRS is not only a reliable method to estimate the total free amino acids, but can also predict the contents of several amino acids at a reasonably accurate level. The prediction statistics of selected amino acids obtained by a filter-type instrument (Technicon Infralyzer 400) and a scanning-type instrument (NIR System 6500) are compared in Table 3. The unsatisfactory results from the filter-type instrument could be due to the limitation of wavelength available. The performance of the scanning-type instrument was much improved. This result suggests that one may be able to use a scanning-type near infrared analyzer to determine some amino acids such as glutamic acid in vegetable soybean seeds individually in a relatively short time.

Table 2. The prediction statistics of carbohydrates of vegetable soybean by NIRS.

Carbohydrate	Content range (mg/g)	No. of samples	R	SEP
Starch	46.90- 98.70	35	0.95	0.52
Total sugar	52.70-117.00	38	0.97	0.33
Sucrose	39.70-102.70	25	0.96	1.17
Fructose	3.29- 14.95	25	0.95	0.67
Glucose	7.35- 13.71	25	0.92	0.17
Raffinose	0.01- 5.72	14	0.73	0.73
Stachyose	0.01- 4.06	14	0.73	0.62
Crude fiber	34.30- 46.30	34	0.96	0.35

Table 3. The prediction statistics of selected amino acids obtained by a filter-type and a scanning-type NIRS.

Free amino acid	Content range (mg/g)	No. of samples	Filter-type		Scanning-type	
			R	SEP	R	SEP
Glutamic acid	1.90-22.58	26	0.89	2.71	0.91	2.01
Alanine	0.24-19.03	26	0.85	3.04	0.89	2.24
Aspartic acid	0.26- 3.60	26	0.81	0.60	0.83	0.60
Tyrosine	0.11- 2.11	26	0.80	0.35	0.82	0.34
Methionine	0.05- 1.80	26	0.80	0.65	0.85	0.54

Analysis of amino acid patterns of three varieties at three harvesting stages suggested that significant variations between content of glutamic acid and alanine can be observed among the varieties tested.

Hardness of Vegetable Soybean

The texture of vegetable soybean is rather complex in nature. There is no standard available on the desired texture for vegetable soybean. The hardness—expressed as the force required to break the vegetable soybean seed—is adopted to evaluate the texture of vegetable soybean at AVRDC (Tsou and Hong 1991). NIRS has made it possible to estimate the hardness of cooked seeds based on the absorption spectrum of flour prepared from uncooked seeds (Table 4). There are also many factors that might contribute to the hardness of vegetable soybean seeds. The possible effects on seed hardness of different varieties, harvest stage and cooking time were studied. Pods after prolonged cooking are generally softer, and therefore the desired hardness can be obtained through the control of cooking time. However, extended cooking time may cause the breaking of pods or degradation of pod color. The hardness of vegetable soybean seeds harvested at different maturity stages is presented in Table 5. Experimental results revealed that there is no significant difference in seed hardness among seed samples that had been harvested between 60% and 100% maturity. This suggests that seed hardness is not a critical factor in determining the date of harvest.

Table 4. The prediction statistics of calibration equation for hardness of vegetable soybean.

No. of filter	Calibration			Performance test		
	R^2	SEC	Slope	Intercept	SEP	R
5	0.92	0.21(35)	0.96	0.14	0.24(38)	0.91

Values in parentheses indicate the number of samples used.

Table 5. The hardness of cooked seeds of three varieties of vegetable soybean harvested at different maturity stages.

Variety	Hardness (%) maturity*			
	60%	80%	100%	LSD
Kaohsiung No. 1	2565**	2628	3297	217
Tzurunoko	2494	3118	3564	194
Ryokkoh	2917	2713	2811	178
LSD	240	197	272	

*Percent of pod; its seed size reaches the full potential.
**Mean value of 10 measurements.

Flavor of Vegetable Soybean

Vegetable soybeans do not have a strong flavor. Nevertheless, trained panels are able to detect the flavor differences among varieties. Variety Kaohsiung No. 1 is claimed to be low in flavor by the Japanese importers. Gas chromatography was used to estimate the concentration of volatiles of blanched vegetable soybeans (Table 6). A lower concentration of total volatiles was found in Kaohsiung No. 1 than in two other varieties. The outcome from GC-MS work identified the major volatiles in vegetable soybeans as l-hexanal trans, 2-hexanal, l-octan-3-ol, and 2-pentylfuran. Most of them are known as beany flavors of the soybean. The contribution of these volatiles to the flavor of vegetable soybean remains to be investigated. The lower concentration of these compounds in Kaohsiung No. 1 could be due to the lack of one isozyme of lipoxygenase in this particular variety.

Table 6. Total peak area of volatiles in three varieties of vegetable soybean.

Variety	Total peak area*
Kaohsiung No. 1	2527118
Tzurunoko	5020246
Ryokkoh	5536021

*Compared by the same internal standard.

Rating of Vegetable Soybean

The overall qualities of food are attributed to several factors, and they are very complex in nature. Panel tests are still the most frequently used method in evaluating the overall quality of food commodities. There are few examples which demonstrate that successful assimilation for panel tests to construct a spectrum database of vegetable soybean by a scanning-type NIRS instrument. Spectrums of 36 samples of three major cultivars have been installed in the database. More samples will be added to the database in 1991. Panels for vegetable soybean evaluation are presently being trained at the Institute of Food Science, National Chung Hsing University. The trained panels are able to detect the varietal difference based on their sweetness, taste, flavor and texture. The relationship between spectrums at near infrared region and panel tests will be studied.

References

Isakasson, T., and Kjolstad, L. 1989. Prediction of sensory quality of peas by NIR and NIT. Proceedings of the 2nd International NIRS Conference, Tsukuba, Japan, 259 - 266.

Liu, C. P., and Shanmugasundaram, S. 1984. Frozen vegetable soybean industry in Taiwan. *In*: Vegetable and Ornamentals in the Tropics, Ali, M. M., and Lim, E. S. (ed.) Proc. of the Symposium on Vegetables and Ornamentals in the Tropics. Selangor, Malaysia. Oct. 27 - 28,1982, 199-212

Masuda, K. 1989. Freezing of vegetables. Freezing, 64(738), 359 - 376.

Masuda, R., Hashizume, K., and Kaneko, K. 1988. Effect of holding time before freezing on the constituents and the flavor of frozen green soybean (Edamame). Nippon Shokuhin Kogyo Gakkaishi, 35(11), 763 - 770.

Shanmugasundaram, S., Tsou, S. C. S., and Cheng, S. H. 1989. Vegetable soybean in the east. *In*: Pascale A. J. (ed.) World Soybean Research Conference IV. Buenos Aires, Argentina, 1979-1986.

Tsou, S. C. S., and Hong, T. L. 1990. Application of NIRS for quality evaluation of soybean and vegetable soybean. Proc. of the Symposium on Improving Nutrition Through Soybean. (In Press). Jilin, China.

Tsou, S. C. S., and Hong, T. L. 1991. Estimating the hardness of vegetable soybean by near infrared reflectance spectroscopy. Journal of Food technology (China). (In Press).

Tsou, S. C. S., Hong, T. L. and Kan, K. K. 1989. Application of NIRS as mass screening technique at AVRDC. Proc. of the Second International NIRS Conference. Tsukuba, Japan.

Williams, D. C., Lim, M. H., Chen, O. A., Pangborn, R. M., and Whitaker, J. R. 1986. Blanching of vegetables for freezing; which indicator enzyme to choose. Food Technology, 130-140.

Yan, S. H., Meurens, M., and Dufour, J. P. 1989. Taste quality control of China tea by NIRS method. Proceedings of the 2nd International NIRS Conference, Tsukuba, Japan, 166-173.

Postharvest Processing, Marketing and Quality Degradation of Vegetable Soybean in Japan

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Abstract

In 1988, Japan produced 104,500 t of vegetable soybean, and imported another 36,842 t mainly from Taiwan. Vegetable soybean is eaten mainly in the summer. Most of the production areas are far from the consumers in large cities, and the soybean is mainly sold as a form of stripped pods. Appearance, such as color and size, are important features in marketing, so postharvest sorting is extremely important. It is difficult to judge the correct time for harvesting, which has considerable influence on quality. Sugars and free amino acids decrease shortly after harvest, and the taste deteriorates, particularly at high temperatures. Precooling at the production site before transporting to the cities is an effective way of maintaining quality.

Postharvest Processing and Marketing

Utilization

There are two forms of vegetable soybean in the Japanese market, fresh and frozen. All vegetable soybeans produced in Japan are consumed fresh. The domestic production was 104,500 t from 14,400 ha in 1988 (Table 1). All of the frozen vegetable soybean was imported: 36,842 t valued at $48.1 million (US$1=135 yen) in 1988 and 34,241 t valued at US$63.7 million in 1989. The soybean was imported mainly from Taiwan (34,001 t), with the balance from China (229 t), Mongolia (10 t), and USA (2 t) in 1989. Imports from Thailand started in 1990. In addition to the frozen soybean, 200-300 t of fresh soybean were imported from Taiwan in the period from December to June when the production is limited and the price is high in Japan.

Table 1. The production of vegetable soybean in Japan.

Year:	1980	1985	1986	1987	1988
Area under cultivation (ha)	14,100	14,300	14,000	14,700	14,400
Yield(t)	118,400	115,500	113,600	116,000	104,500

From: Statistics of Vegetable Production (Ministry of Agriculture, Forestry and Fisheries).

Ninety-one percent of the vegetable soybeans are consumed during June-September, with 60% in August and September. Vegetable soybeans are eaten as a side dish, particularly with beer. The pods are lightly cooked in boiling water for 5-10 min with a little salt. Japanese people take great pleasure in the taste and flavor of soybean. The frozen form is mainly for business use, and the fresh soybean is preferred at home.

Marketing

For marketing, the fresh vegetable soybeans are sold in two ways: one is with the pods attached to the stems with leaves and roots, and the other is with the pods stripped from the stem. Historically, vegetable soybeans were cultivated near the consuming areas and sold on the stem with leaves and roots. However, the stripped pods are more commonly found now. For example, at the Tokyo market, the production area is Gunma, Niigata and Iwate, areas far from Tokyo. Therefore, the stripped pods are preferred for such long-distance transport and to reduce waste.

Most vegetable soybeans are harvested by hand. When the vegetable soybeans are sold in markets still attached to the stems, the plants are hand-cut or pulled out by the roots, and unacceptable pods and lower leaves are culled, and the branches tied together in small bundles. For the sale of pods alone, plants are cut and the pods are stripped off. After sorting, 300-500 g of pods are put into a polyethylene net-bag and 10 or 20 bags are packaged in a corrugated cardboard box. Electric powered, stationary pod strippers are also available and commonly used. It takes 90.2 hours to cover 0.1 ha by hand, and 17.2 hours using the stripper.

Those pods having only one seed, immature, injured, or diseased are removed by hand. This is a costly operation. About 70% of the production time for vegetable soybeans is at the postharvest and processing stages, such as harvesting, stripping pods, sorting, and packaging. However, because the value of vegetable soybeans at market is mainly determined by their appearance, the sorting process is extremely important, and a producing area that excels at processing and sorting will be given a superior rating by consumers. There are many sorting standards in each production district.

In Iwate Prefecture, the special grade of vegetable soybean should have 90% or more pods containing two or three seeds. The pods should be perfectly shaped, completely green, no injuries, and no spots. The grade B vegetable soybean should have 90% or more pods with two or three seeds, but it can be a lighter green, slightly spotted, injured, or malformed, and have short pods or small seeds. The grade A is the intermediate between special grade and grade B. In these three grades, pods must not be overly mature, diseased, insect-damaged, one-seeded, malformed, yellowed, split, spotted, or unripe.

Period of Harvest

In marketing quality of vegetable soybean, the appearance has priority over taste. However, taste is an important factor, but there is no method to evaluate it in marketing. Because the quality is mainly evaluated by appearance, the superiority or inferiority of production districts is decided with the propriety of harvest period and of the postharvest processing. It is always difficult to decide the period for harvesting, because the pods are still filling. To determine the most suitable period for harvesting, the relationships of days after flowering, pod expansion, seed component, and pod color have been investigated.

The length and width of pods can be known at a relatively early growth period, and thereafter seeds rapidly expand. The thickness and weight of pods increases following the pod expansion. Taste of the vegetable soybean is highly correlated to the sucrose content or glutamic acid of seed (Masuda et al. 1988). Therefore, the sugar and free amino acid contents were estimated. The taste is known to deteriorate in the late growth stage, mainly due to the decrease in content of sugars. However, the sugar did not decrease in our case. The sugars were composed of sucrose, fructose and glucose. Sucrose content was always high. Judging by pod expansion, fructose and glucose decreased, while sucrose increased. Total sugars gradually increased at the early stage of pod expansion, and remained static after the middle stage. Free amino acids decreased during seed expansion (Table 2). The major forms of the free amino acids were aspartic acid, histidine, alanine, and glutamine.

Pod color is important for evaluation of the grades (Table 3). It was measured using a colorimeter (Minolta CR-100) and expressed according to a Lab color system which was recommended by the Committee of International Illumination (CIE, Commission Internationale de I'Eclairage). During the ripening, the "L" value (0 = white and 100 = black) increased and the "a" value (+ = red and - = green) also increased in minus value. On the other hand, there was no change in the "b" value (+ = yellow and - = blue). Therefore, the "X" (color index) which was calculated from the following equation, $X=L \times b/|a|$ showed an increase following the pod color deterioration. The thick pods at harvest showed faint color and continued to reduce their color after harvest.

Table 2. Relation between days after flowering and content of free amino acid (mg/100 g FW).

Days after flowering:	25	28	32	34	36	39	42	47	50
Aspartic acid	27.7	24.5	34.6	22.5	21.7	30.3	26.2	29.3	16.5
Serine	17.5	15.8	14.3	17.6	15.5	16.5	19.2	16.8	13.5
Asparagine	467.6	413.9	436.0	443.4	337.6	304.2	252.0	180.0	148.6
Glutamic acid	98.7	117.1	188.8	251.0	153.3	156.6	218.6	172.6	124.9
Glutamine	186.8	130.9	85.0	108.2	51.9	45.7	32.8	10.1	9.6
Alanine	46.0	46.5	66.9	164.3	82.0	80.6	82.5	51.2	74.6
Histidine	90.0	89.9	55.2	49.8	41.8	34.1	19.1	13.7	13.5
Arginine	48.6	43.4	47.7	44.6	35.5	25.7	24.1	15.8	12.3

Table 3. Relation between thickness of pod and pod color at harvest or after storage.

Pod thickness (cm)	~0.84				0.85~0.95			
Pod color	L	a	b	X	L	a	b	X
At harvest	61.0	-19.1	41.0	131	59.2	-19.4	41.2	126
After storage	60.9	-18.8	41.1	133	60.8	-18.7	41.3	134
Pod thickness (cm)	0.96~1.04	1.05~						
Pod color	L	a	b	X	L	a	b	X
At harvest	59.3	-19.4	41.7	128	59.0	-19.6	43.1	130
After storage	60.6	-18.5	42.1	138	62.6	-18.3	43.2	148

Storage conditions: temperature 25°C, period 3 days.

Good qualities of vegetable soybean are good taste, deep-green color of pods, full expansion of pods, uniform pods without infections or injuries. To obtain uniform pods, it is important to protect plants against diseases and insects. The other three factors can be related to the time of harvest. The relation of days after flowering to these factors is shown in Table 4, using a variety, Sapporomidori. Concerning taste, content of free amino acids decreased following pod expansion, so it is better to harvest as early as possible. On the other hand, content of sugars was low before 35 days after the flowering and maintained the relatively higher level after 35 days. Taste is decided not only through content of both sugars and free amino acids, but also flavor and texture. Using pod color as a guide, it is suitable to harvest before 40 days after flowering, since the thick pods deteriorate after harvest. Furthermore, full expansion is the equivalent of thick pods so that it is better to harvest as late as possible.

It is best to harvest Sapporomidori 36-39 days after flowering when the pods are 0.85-0.95 cm thick. We found the same values of thickness with two other varieties, Fukura and Kinsyu. These size criteria can be used for other varieties having different characteristics of maturity and pod size. The relation of pod thickness to days after flowering is given in Table 5. At the best harvest time for each variety, around 40% of the total pods per stem are of adequate thickness. This means that the postharvest sorting is extremely important. The pod thickness increases more rapidly than we expected, suggesting that the most suitable range for harvest is very limited, i.e. only 2 or 3 days during the growth period.

Table 4. Relation between days after flowering and each factor for judging quality.

Days after flowering:	30	40	50
Taste			
Free amino acids	Good	Normal	Bad
Sugars	Bad	Good	Good
Pod color	Good	Good	Bad
Degree of pod expansion	Bad	Normal	Good

Table 5. Relation between days after flowering and thickness of pod.

Variety	Days after flowering	Thickness of pod (cm) ~0.79	0.80~0.84	0.85~0.94	0.95~0.99	1.00~
Sapporomidori	28	98	1	1	0	0
	32	73	21	6	0	0
	34	42	22	36	0	0
	36	33	17	40	7	4
	39	29	11	28	15	18
	42	13	4	37	12	35
	47	13	6	22	15	44
	50	6	1	4	6	83
Fukura	34	100	0	0	0	0
	38	79	15	6	0	0
	40	56	17	26	0	0
	42	32	10	43	10	5
	45	28	10	36	12	15
	48	11	3	26	15	46
Kinsyu	45	80	16	5	0	0
	48	38	20	38	5	0
	52	16	7	32	19	27
	56	7	4	38	19	32
	59	8	0	22	13	56
	63	3	0	6	5	86

Quality Degradation

Research concerning quality degradation has been limited. Vegetable soybeans belong to the vegetable group with a high rate of respiration. After harvest, sugar content decreases rapidly at high temperatures (Table 6). Free amino acids also decrease in a short period; content of alanine and glutamic acid was reduced to two-thirds and one-half of the harvest, respectively, when the pods were placed under room temperature (26±2°C) and 66% humidity for 24 hours. In this case, a decrease in sweetness and taste could be recognized after 10 hours (Masuda et al. 1988).

Table 6. Effect of storage temperature on sugar content.

Storage	After harvest				
temp. (°C)	8 hours	24 hours	48 hours	4 days	7 days
0	98[a]	100	100	83	76
20	82	68	48	27	25
28	85	59	36	25	

[a]Values are indicated as the percentage of total sugar content relative to the 0 time at harvest (2.26 g/100 g FW).

The changes in the quality of pods attached to the stem with leaves and roots or of the stripped pods were studied post harvest. It was reported that either the pods on the stem possessed better quality than stripped pods (Iwata et al. 1982), or stripped pods were better (Osodo 1978). This needs further clarification. The Iwata et al. (1982) report showed that the pod color was maintained as green by wrapping with a low-density polyethylene film. The pod color deterioration is accelerated under low humidity conditions, whereas deterioration is prevented under high humidity.

The pods stripped by machine often turned brown after 2 or 3 days, because the browning substances are enzymatically synthesized within the injured cells, such as by phenoloxidases.

Quality Maintenance

Handling soybeans under cool conditions is important to maintain their high quality, so precooling in Japan is carried out at the shipping house of a production district prior to transport to consumers. In fact, most vegetables are precooled in summer, in two ways: (1) air-cooling and (2) vacuum-cooling. For vegetable soybeans, vacuum-cooling is effective in maintaining their good quality, because the temperature can be reduced quickly. It is important for quality maintenance to save time in harvesting and sorting to the start of precooling. Vegetable soybeans are usually transported to cities by truck.

Vegetable soybeans are packed in net bags and then put into corrugated, cardboard boxes. The following ideas should help maintain the soybeans in high humidity by: (1) spreading the sucking-water sheets in a box, or (2) preventing transpiration and simple controlled atmosphere effects by wrapping the soybeans with polypropylene film instead of the net bag. Use of these materials is planned not only for quality maintenance but also to compete with other production areas. The high humidity seems effective in preventing wilting and maintaining a deep green pod color.

References

Iwata, T., Sugiura, H., and Shirahata, K. 1982. Keeping quality of green soybeans by whole plant packaging. Engei Gakkai Zasshi, 51,224-230 (in Japanese with English summary).

Masuda, R., Hashizume, K., and Kaneko, K. 1988. Effect of holding time before freezing on the constituents and the flavor of frozen green soybeans (edamame). Nihon Shokuhin Kogyo Gakkaishi, 35,763-770 (in Japanese with English summary).

Osodo, K. 1978. Technology of quality maintenance and storage for vegetables. Ministry of Agriculture, Forestry and Fisheries (Practical Report), 54,1-39 (in Japanese).

Studies on the Effects of Cold Storage and Precooling on the Quality of Vegetable Soybean

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Abstract

Vegetable soybean is an important export vegetable in Taiwan. To prolong its storage life, cold storage conditions were studied. In one set of tests, vegetable soybeans with pods were packed in four kinds of bags (PP, PE with ethylene absorbent, ethylene absorbing film and net bag) and stored at 0°, 5° and 20°C to compare the quality during storage, changes in weight loss, vitamin C content, color index and hardness. Samples packed with the three kinds of plastic bags gave similar results, maintaining better quality than the net bag packed ones. The best storage temperature was 0°C. In a second set of tests, precooling effect was investigated. Quality was analyzed after precooling and storage at 0°C. Vegetable soybeans precooled in 0°C iced water, packed in PE bags with ethylene absorbent, and stored at 0°C maintained the best quality during storage.

Introduction

Vegetable soybean (*Glycine max*) is popular in Asia. It is rich in protein and vitamins, and consumed with or without pod. However, only the beans are eaten.

Some reports indicate that vegetable soybean quality might change during cold storage, e.g. loss of moisture, vitamin C, sugar and amino acid, and chlorophyll degradation (Iwata and Shirahata 1979; Iwata et al. 1982). Proper storage conditions are essential for vegetable soybean to maintain its quality. Tsay et al. (1990) reported that 1°C is the best temperature for vegetable soybean storage. PE or PP bags with 0.32% pores also can maintain good quality of vegetable soybeans (Akimoto and Kuroda 1981). According to the results of Hsieh and Tsay (1975), 3°C is the best precooling temperature for vegetable soybeans.

The object of our study was to investigate the effects of different storage conditions on the quality of vegetable soybeans (e.g. packaging method, storage temperature, and precooling conditions), to determine the best conditions to prolong shelf-life and maintain quality.

Materials and Methods

Two vegetable soybean cultivars were used, harvested from a farm in Pingtung County. The cultivars used in the packaging and precooling tests were #205 (Tzurunoko) and Kaohsiung Selection No. 8, respectively.

Packing

Three kinds of plastic bags, (polyethylene (PE) (13.6 x 16.5 cm), polypropylene (PP) (19.8 x 25.1 cm) and PE with ethylene absorbent, were used as packaging material, with net bags used as the control. In the precooling test only the PE and net bags were used.

In the study of packaging conditions, 200 g of vegetable soybeans were packed in four different bags and samples were stored at 0°, 5° and 20°C. In the precooling study, we used iced water as the cooling medium and the ratio of sample and water was 1:3. Then we stored precooled and unprecooled samples at 0°C. Every sample was analyzed for weight loss, vitamin C, color index and hardness every 4 days during 28-day storage.

Weight Loss

Every sample was weighed every 4 days, and all tests were repeated three times.

Vitamin C Assay

Vitamin C content was assayed according to the method of the Pharmaceutical Society of Japan (1973). Five-gram (W) samples were blended with 3 ml 0.3% metaphosphoric acid (containing 0.8% acetic acid), diluted with this solution to 50 ml (V_1) then filtered to obtain the filtrate. Five milliliters of filtrate (V_2) mixed with 5 ml metaphosphoric acid and titrated with indophenol (containing 0.025% 2,6-dichlorophenol indophenol-Na and 0.025% $NaHCO_3$) to a pink color. The titration volume was S ml, and the titration volume of 5 ml 0.02% vitamin C standard was T ml. The vitamin C content was calculated using the following formula:

L-ascorbic acid (mg/100g) = $(S \times V_1) \times 100 / (T \times V_2 \times W \times K)$.

Each sample was analyzed twice.

Color Measurement

Sample color is measured by a 1000 DP color and color difference meter (Nippon Denshoku Co.) The color index was calculated according to the following formula:

$L \times b / |a|$

where L = 0 indicated white and L = 100 indicated black, a = + indicated red and a = - indicated green, and b = + indicated yellow and b = - indicated blue.

Each datum point was a mean of 15 measured three times.

Hardness Assay

The hardness of sample was measured with a fruit pressure tester (model FT 327). Every sample was measured three times.

Results and Discussion

Packaging Test

The weight loss of vegetable soybean during storage is shown in Fig. 1a. When the storage temperature was higher, the weight loss was higher. The samples were assayed at 20°C only to 16 days and ended because of molding. After storage for 16 days, the samples stored at 5 and 20°C in PE bags with ethylene absorbent also maintained more than 99 and 97% fresh weight (Fig. 1). But the cold storage samples of net bags maintained only 80% fresh weight and the samples stored at 20°C lost 70% of their fresh weight (Fig. 1b).

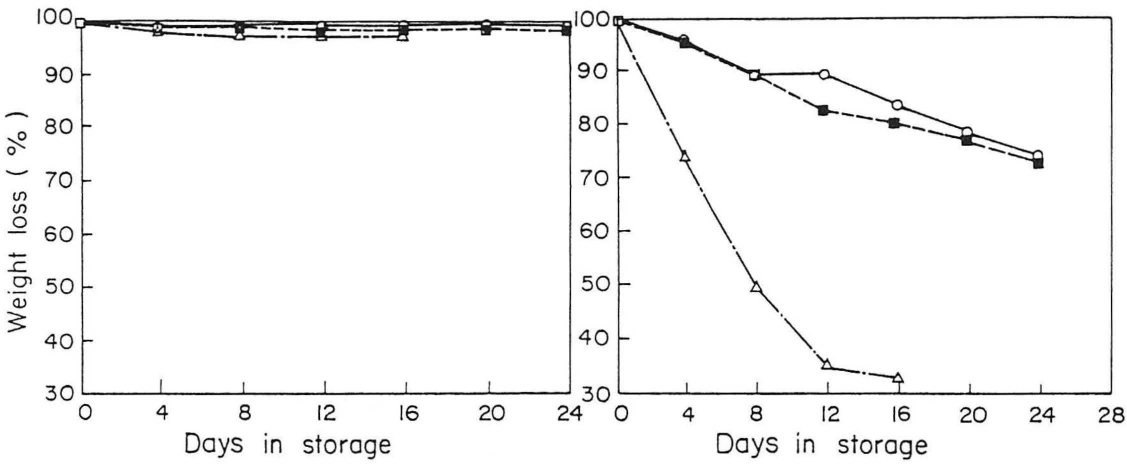

Fig. 1. Changes in weight loss of vegetable soybeans packed in (a) PE bags with ethylene absorbent and (b) net bags during storage at different temperatures.

The changes in vitamin C content of samples in PE bags are shown in Fig. 2a and 2b. Regardless of storage temperature or packaging material used, vitamin C content decreased during storage. The vitamin C content in 0°C-stored samples decreased least. Iwata and Shirahata (1979) and Salunkhe et al. (1985) also found that vitamin C content in soybean decreased during storage. Color index calculated with Hunter's value (L x b/lal) can represent the yellowing of vegetable soybeans (Iwata and Shirahata 1979): The higher the value, the yellower the sample. The color index of all samples increased during

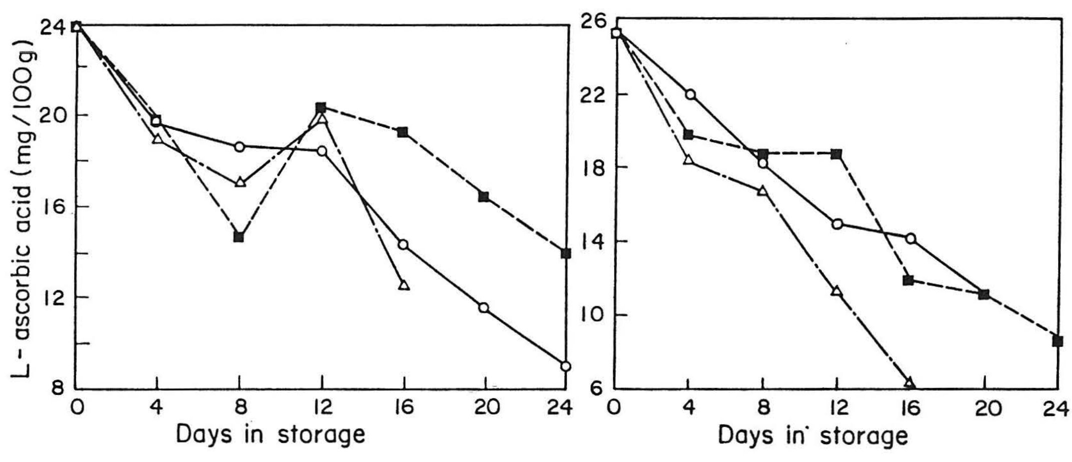

Fig. 2. Changes in vitamin C (L-ascorbic acid) content of vegetable soybeans packed in (a) PE bags with ethylene absorbent and (b) in net bags during storage at different temperatures.

storage, indicating that all samples were getting yellow during storage (Fig. 3a and 3b). The samples stored at 0°C had the lowest changes in color index. However, after storage at 0°C for 24 days, the color index of net bag-packed samples was 1. times that of the PE bags packed with ethylene absorbent.

The hardness of all samples increased during storage (Fig. 4a and 4b), with the 20°C-stored samples having the highest increase. The 0° and 5°C-stored samples had similar profiles, and the samples in net bags became harder than those packed in PE bags with ethylene absorbent.

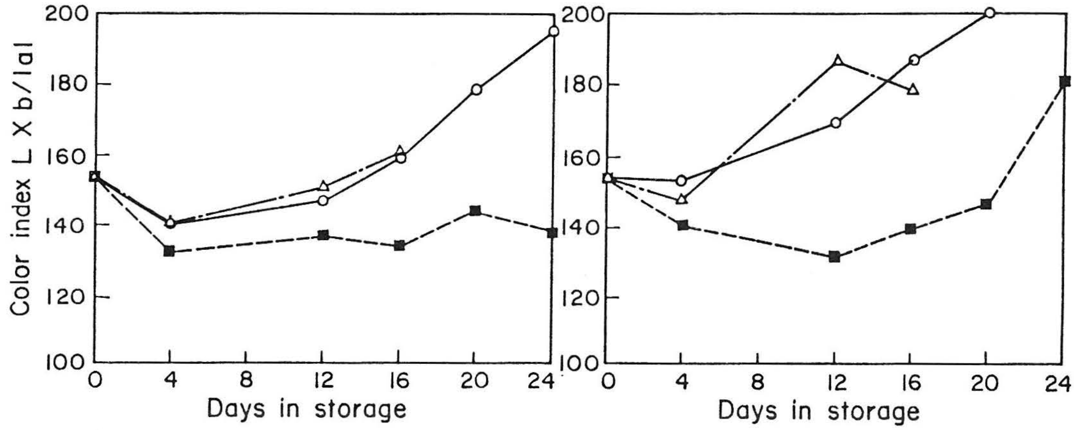

Fig. 3. Changes in color index of vegetable soybean packed in (a) PE bags with ethylene absorbent and (b) net bags during storage at different temperatures.

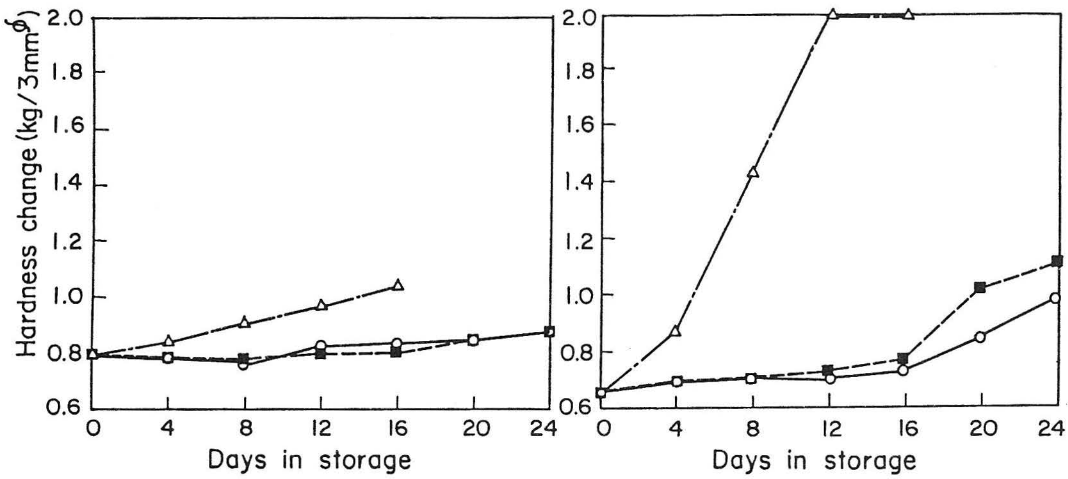

Fig. 4. Changes in hardness of vegetable soybeans packed in (a) PE bags with ethylene absorbent and (b) net bags during storage at different temperatures.

Because the results of PP-packed and ethylene-absorbing film were similar to those of PE bags with ethylene absorbent, only the results of PE bag-packed with ethylene absorbent and the net bag-packed samples are shown.

From the results mentioned above, the three kinds of plastic packaging materials had similar effects on the quality of vegetable soybeans during storage, and maintained better quality than the net bag-packed. However, cold storage at 0 and 5°C was more suitable for vegetable soybeans than 20°C.

Precooling Test

The weight losses of two different packaging materials with or without precooling are shown in Fig. 5a and 5b.

After storage at 0°C for 28 days, the weight of samples in PE bags with ethylene absorbent was almost the same as the fresh samples, however samples in net bags lost weight quite rapidly.

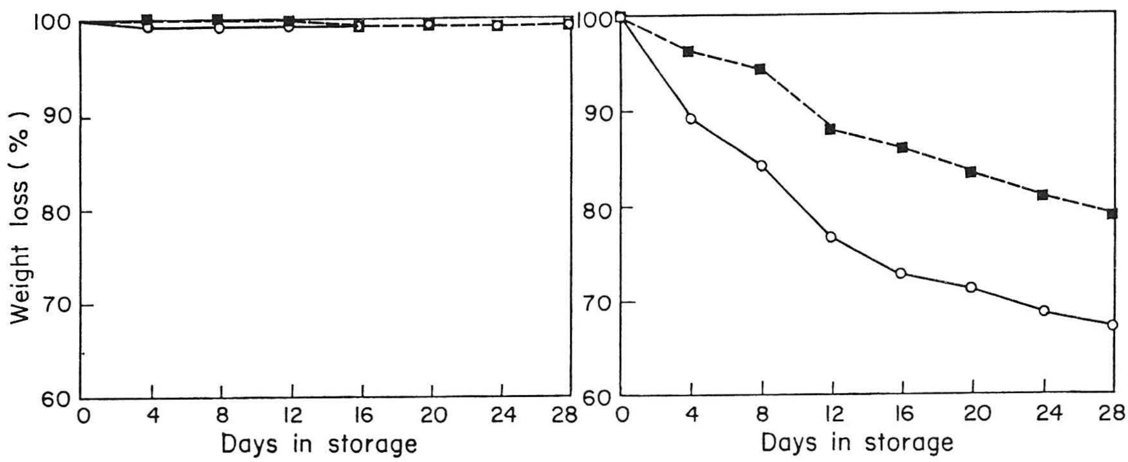

Fig. 5. Changes in weight loss of precooled and non-precooled vegetable soybeans packed in (a) PE bags with ethylene absorbent and (b) in net bags during storage at 0°C.

The color index of samples in net bags began to increase after 20 days of storage, and the samples without precooling yellowed more rapidly than precooled ones. The color index of precooled samples packed in net bags almost doubled the non-precooled ones after 28 days of storage (Fig. 6a). However, the samples in PE bags with ethylene absorbent almost maintained the same color index as fresh ones. The samples precooled remained greener than non-precooled ones (Fig. 6b).

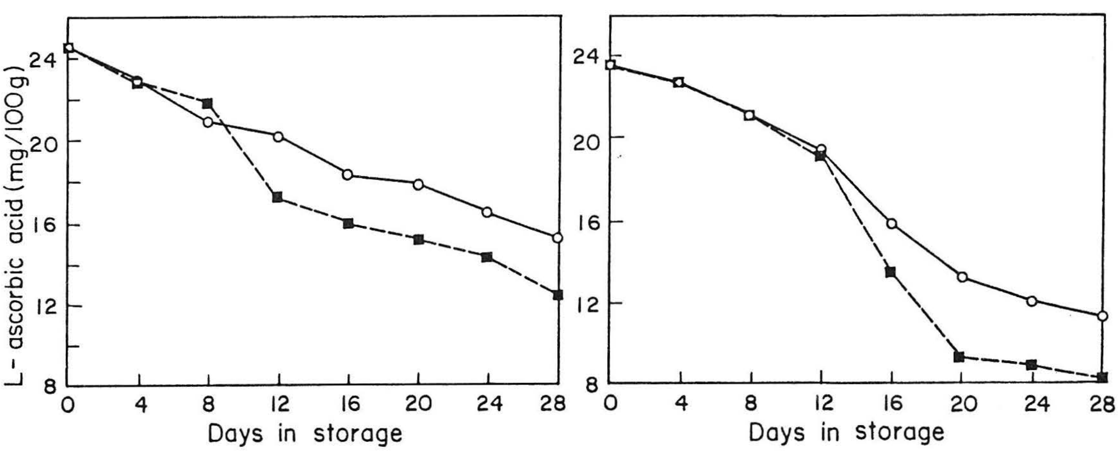

Fig. 6. Changes in vitamin C (L-ascorbic acid) content of precooled and non-precooled vegetable soybeans packed in (a) PE bags with ethylene absorbent and (b) net bags during storage at 0°C.

The changes in vitamin C content in the samples packed in two kinds of materials are shown in Fig. 7a and 7b. Regardless of the kinds of packaging materials used, the precooled samples maintained higher vitamin C content than non-precooled ones. The vitamin C content of precooled samples in PE and net bags decreased 38 and 52%, respectively, after being stored at 0°C for 28 days. The non-precooled samples in PE and net bags decreased 50 and 64%, respectively, during the same period. The results indicated that precooling of vegetable soybeans and packaging in PE bags with ethylene absorbent might maintain the vitamin C level best during storage for 28 days.

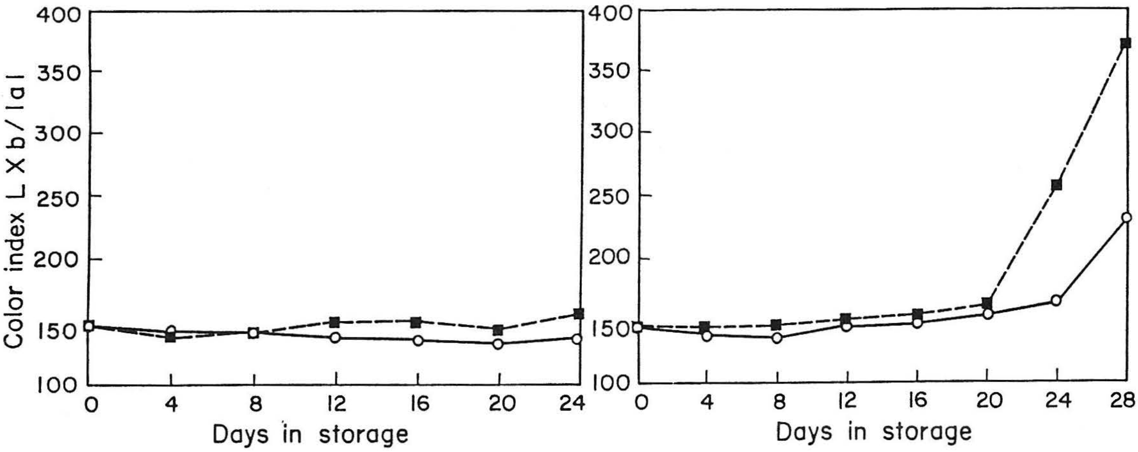

Fig. 7. Changes in color index of precooled and non-precooled vegetable soybean packed in (a) PE bags with ethylene absorbent and (b) net bags during storage at 0°C.

The hardness changes during storage are given in Fig. 8a and 8b. Samples from four treatments showed the same tendency in hardness change. The hardness increased initially and then decreased after 16 days of storage.

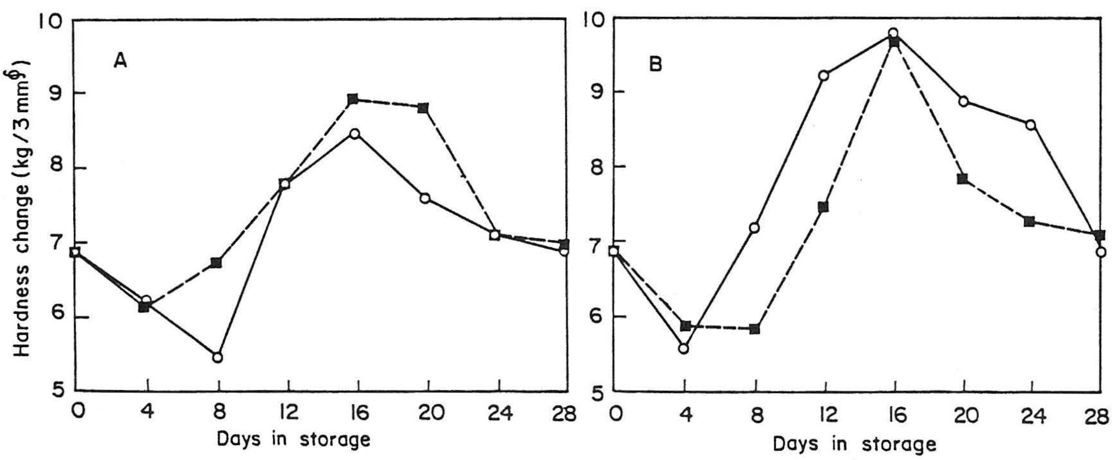

Fig. 8. Changes in hardness of precooled and non-precooled vegetable soybeans packed in (a) PE bags with ethylene absorbent and (b) net bags during storage at 0°C.

These results indicate that precooling was effective in maintaining better quality vegetable soybeans during storage. Hsieh and Tsay (1975) indicated that 3°C precooling treatment may maintain the quality of vegetable soybean. The PE bag-packed samples retained more vitamin C, remained greener and suffered less weight loss than that packed in net bags. We found that the best storage conditions for vegetable soybeans included packing in PE bags, precooling and storing at 0°C.

References

Akimoto, Kouichi, and Kuroda, Suketoshi. 1981. Quality of green soybeans packaged in perforated PE/PP film. J. Japan Soc. Hort. Sci., 50, 100-107.

Hsieh, J. F., and Tsay, K. H. 1975. Study of post-shelling treatment for vegetable soybean. 1985 Report on Agricultural Machinery Research, Development and Demonstration, 116-118.

Iwata, Takashi and Shirahata, Kei-ichi. 1979. Keeping quality of green soybeans. The factors concerning postharvest quality deterioration and the effects of atmosphere and whole plant packaging. J. Japan Soc. Hort. Sci., 48, 106-113.

Iwata, Takashi, Sugiura, Hirotaka, and Shirahata, Kei-ichi. 1982. Keeping quality of green soybeans by whole plant packaging. J. Japan Soc. Hort. Sci., 51, 224-230.

Pharmaceutical Society of Japan. 1973. Quantitative analysis of vitamins. Notes on Sanitary Experimental Method, 151-153

Salunkhe, D., Kadam, K., and Chavan, S.S. 1985. Nature and causes of losses. *In*: Postharvest Biotechnology of Food Legumes. Boca Raton, Florida: CRC Press, Inc., 79-102.

Tsay, L.M., Sheu, S.C., and Wu, M.C. 1990. Studies on the quality changes of green soybean during storage. J. Chinese Soc. Hort. Sci., 36(3), 210-222.

A Critical Analysis of Vegetable Soybean Production, Demand, and Research in Japan

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Abstract

Soybeans have probably been consumed at an immature stage as vegetables as long as soybeans have been eaten, particularly as a medicine in early history. In Japan, vegetable soybeans, locally called edamame, evolved from a sacred offering and food for religious purification to popular street fare and a snack to eat with beer which has a sweet savory flavor distinct from grain soybeans. The spread of refrigeration and affluence has increased their popularity; currently there is a 10,000 t gap in supply and demand. In over 160 reports published in Japan since 1920, most research has focused on crop and postharvest management. Little research has been carried out on the genetics of quality, plant pathology, or plant physiology, but over 400 varieties of vegetable soybean have been developed and released. In spite of its popularity in Japan, cultural differences, language, geography, and commercial rivalries have hindered the development of this crop on a global scale.

Introduction

The first historical reference to soybeans is thought to be in 664 B.C. from records describing tribute paid to the Chou dynasty by the Shan-Jung tribe of Northeast China, where wild soybeans are found (Ho 1974). At that time, soybeans were called *Jung Shu*, a bean of the Jung. However, it is thought that soybeans may have entered the domestication process hundreds of years earlier.

Observing the consumption patterns of most grain legumes, it is probable that immature soybeans may have been gathered and eaten for as long as mature soybean seeds have been eaten. Among small-scale intensive farmers who grow soybeans in Asia, most will harvest grain soybeans at an immature stage to cook and consume as a vegetable. This practice is probably as old as the domestication of soybeans and may date from pre-agriculture periods.

The earliest specific reference to the consumption of immature soybeans as a vegetable is found in the second century B.C. publication, *Spring and Autumn Annals* (*Ch'un Ch'iu*), which was mentioned in Wu Ch'i-chun's chapter on soybeans in the book, *Chih Wu Ming Shih T'u K'ao*, published in 1848 and translated by W.J. Hagerty of the US Department of Agriculture in 1917 (Shurtleff and Aoyagi 1991). Wu notes the earlier reference to vegetable soybeans enhancing the yang principle, and so having medicinal value.

In most of East Asia, vegetable soybeans are harvested and sold as pods-on-stems, loose pods, or shelled beans (*mao dou* in China, *edamame* in Japan, and *poot kong* in Korea). The pods-on-stems form is no longer commonly consumed in China or Korea, but is still a popular form in Japan, partially because appearance and flavor factors decline more slowly after harvest while pods remain attached to the stem. In China, vegetable soybeans are usually cooked as shelled immature seeds, but sold in the pod or shelled; they are used primarily as an ingredient in stir fry dishes. In Korea, the beans are added to rice and cooked together (*pub mi kong*). In Japan, vegetable soybeans are usually sold as loose pods, occasionally on the stem, and rarely shelled, although shelled forms have been used to make a sweetened paste (*zunda*—see Nagamine 1989; Furusawa 1984) and edamame tofu (Yamauchi 1990).

Soybeans were probably brought to Japan from Korea and the Shanghai area of China (Hymowitz and Kaizuma 1981) during the Yayoi period (200 B.C. to 250 A.D.) and are mentioned in the Japanese historical reference, *Record of Ancient Matters* (*Kojiki*) published in 712 A.D. Summer-type soybeans were brought to Kyushu and fall-type soybeans to the Tohoku region of Honshu Island and Hokkaido, respectively.

References to immature soybeans (*nama daizu*, later *aomame*) also appear in the 8th century A.D., when it is described as one of the sacred food offerings used in *Shinsen*, mentioned in the record book of a royal treasure house called the Shosoin in the capital city of Nara (Yamauchi 1990). *Aomame* is mentioned in the *Engishiki*, a guide to the conduct of government and religious affairs published during the Heian period in 927 A.D. (Igata 1977). Later, cultivation methods for vegetable soybean were published in the book, *A Complete Book of Farming* (*Nogaku Zensho*) published in 1697 (Gotoh 1984).

Until the modern cash crop era, there was little demand or selection pressure for vegetable-type soybeans, except to serve the needs of special urban and aristocratic populations. However, the selection of soybean land races for good vegetable qualities occurred gradually over the centuries.

In Japan, the earliest forms of immature vegetable soybeans were called *eda-nari-mame* (branch-fruiting-bean) or *azemame* (rice-bund-bean) and were probably not well distinguished by the characteristic sweet, savory flavor of current edamame until the Kamakura period (1192-1336) or later, when they became part of Buddhist cuisine. By the middle Edo period, vegetable soybean harvest had advanced from October to August and farmers' wives began selling boiled stems with attached pods on the streets of Edo (early Tokyo), particularly during the Festival of the Dead (*Obon*) in August. At that time, vegetable soybean began being used as it is used today, i.e. as a snack food, hor d'oeuvre, or appetizer, usually with alcohol consumption, which explains one of its English nicknames: Beer Bean.

The dramatic increase in affluence and beer consumption following the Meiji Restoration in 1868 can be partially attributed to the large-scale import of European technology, including German technology for beer production. The culture which centered around drinking and snacking expanded, creating a strong demand for vegetable soybeans. The saltiness of the beans is thought to be the perfect complement to beer. The increase in vegetable soybean consumption resulted in it gaining the attention of agricultural and food scientists, and the development of over 400 varieties. Vegetable soybean has now become so distinct from soybeans in the minds of urban consumers that most do not recognize it as the same species as soybeans.

With that short introduction to the history of edamame, the remainder of this paper will attempt to analyze the changes in vegetable soybean production, demand, and research that have occurred in Japan during this century and discuss research directions where constraints are occurring.

Trends in Production and Demand

Demand for vegetable soybean in Japan is thought to have evolved through four phases in society, in addition to its routine use by farm families (Konovsky et al. 1991). The first was as a sacred offering to the *Kami* during the Nara period (*Shinsen*), the second as a food for religious purification during the Kamakura period (*Shojin Ryori*), the third as popular street fare among the Samurai during the Edo period, and the fourth, after the Meiji Restoration in 1868, when it became the most popular accompaniment for beer. As mentioned earlier, the meteoric rise in vegetable soybean consumption closely parallels the increase in beer consumption because of the complementary nature of the saltiness of vegetable soybean and the taste of beer (Fig. 1).

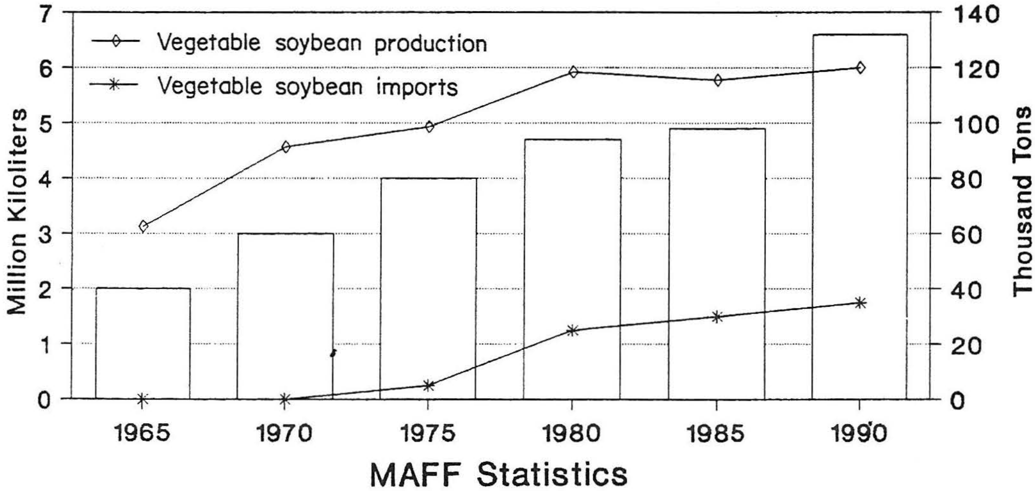

Fig. 1. Beer sales in Japan.

The second major impetus to vegetable soybean production was the spread of refrigeration, first to the commercial sector, especially to bars and beer gardens in the post-war period, and later to the residential sector in the late 1960s and early 1970s when household refrigerators became widely used. The commercial sector currently uses about 65% of frozen vegetable soybean, while the residential sector uses about 35% (Mitsubishi Corporation 1989). The year-round consumption of vegetable soybean has increased in line with the growing popularity of frozen foods in general.

A current major impetus to the use of frozen vegetable soybean is the changing role of women in Japan. More than half of all Japanese women are now employed outside of the home, and are thus becoming more unwilling and unable to prepare elaborate meals from basic ingredients. This situation, along with greater affluence, has greatly increased the appeal of convenience foods. Both precooked frozen and delicatessen-prepared vegetable soybean are products of considerable growth potential.

Frozen vegetable soybean is thought to have been marketed in Japan after World War II, but large-scale distribution did not begin until 1965 (Japan External Trade Association 1983), about the time the Ministry of Agriculture, Forestry, and Fisheries began keeping formal production statistics for vegetable soybean. Production in Taiwan began around 1966, when several large, Japanese trading companies introduced it as an export crop, and exports to Japan began around 1972 (Liu and Shanmugasundaram 1982).

Japanese production statistics from 1946 to 1988 are presented in Fig. 2. Total domestic production of vegetable soybean pods has gradually increased from 30,100 t in 1946 to a peak of 121,900 t in 1982. After a second peak of 120,100 t in 1984, production has fallen. In 1988, production of pods dropped to a decade low of 105,000 t because of an unusually cold growing season (Tohoku Agricultural Experiment Station 1990). Interestingly enough, yields were highest in 1969 verging on 10 t/ha, and dropped to a low of 7.3 t/ha in 1988. Yields in the early post-World War II years were 4-5 t/ha.

The fluctuation in yield can probably be explained by two changes in the crop management system. After the end of World War II, the increased use of chemical fertilizers continually boosted yields to their 1969 peak. During these years, most vegetable soybean was planted in fields and harvested in August and September. Now, much of the vegetable soybean is planted in plastic mulch production systems using vinyl tunnels to cover the plants in early spring. Using such systems, harvest can begin as early as the end of May.

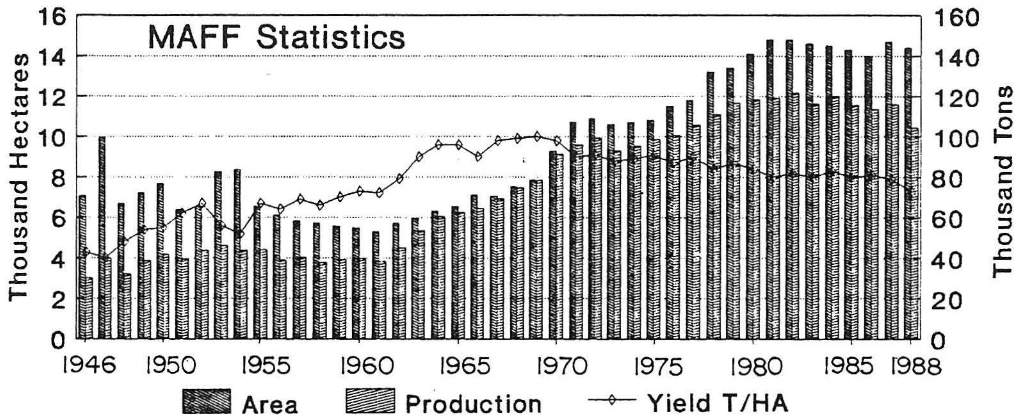

Fig. 2. Vegetable soybean area and production in Japan.

The advancement of the growing season allows farmers to take advantage of higher wholesale prices for vegetable soybean in May and June. For example, in 1989 the price of vegetable soybean was 1033 yen/kg in May, 830 yen/kg in June, and only 519 yen/kg in September (1 US$ =146 ¥ in 1989) (Tokyo Wholesale Market Statistics 1990). However, while receiving a higher price for early production and harvest, the yields are lower. The environmental stress placed on the plants because of the cooler growing temperatures decreases the size and number of vegetable soybean pods.

Future production trends for vegetable soybean in Japan are hard to predict. There are two opposing forces at work. As is well known, farming in Japan, particularly land and labor, is expensive, small-scale, and labor-intensive with a declining agricultural labor force. These facts make it impossible for domestic production to keep pace with the price of imports.

Agricultural land is being converted to other uses, and total domestic agriculture production is falling. However, the greatest pressure is on rice production. World leaders are pressuring Japan to open its rice market to imports, but Japan still produces a surplus of rice. To solve this discrepancy, wherever possible, rice paddies are being actively converted to upland crops through programs sponsored by the Ministry of Agriculture, Forestry, and Fisheries and Prefectural Departments of Agriculture (see Ota 1976a,b,c).

Vegetable soybean is a high-priced commodity and a favorite choice of farmers when converting their paddy fields to upland crops. The opposing forces of (1) inability to compete and (2) conversion to upland crops will probably balance each other out, and vegetable soybean production will remain stable for the fresh produce in the near future.

Although statistics on demand are unavailable, vegetable soybean buyers from major supermarket chains and trading companies insist there is currently about a 10,000 t gap between production and demand. Supermarkets and trading companies feel they could sell about 10,000 t more frozen vegetable soybean than they have available. The growing affluence of Japanese consumers is likely to enlarge the gap, since vegetable soybean is the perfect, healthy fast food!

In spite of rumors of the Americanization of the Japanese diet, traditional foods like vegetable soybean remain popular even among younger consumers (Jussaume 1989; Cook 1988). If production remains stable in Japan and Taiwan cannot supply more vegetable soybean at a reasonable cost, Japanese vegetable soybean buyers will be forced to look to other countries like China, Thailand, New Zealand, and the United States to fill the already existing demand. If vegetable soybean production falls in Japan or Taiwan, or affluence further increases demand in Japan, other countries producing vegetable soybean will have an even larger market available.

Trends in Research

Konovsky et al. (1991) have reviewed more than 160 Japanese publications concerning vegetable soybean concentrating on the period from 1970 to the present. Although space does not permit a review of all the papers here, a complete list is presented in the bibliography.

More than 120 of the articles are in scientific journals dating from 1921 to the present (fewer than five articles per year until the 1980s and 1990s). Most research reports about vegetable soybean are published in journals such as *Daizu Geppo*, *Engei Gakkai Taikai Kenkyu Happyo Yoshi*, *Engei Gakkai Zasshi*, *Ikushugaku Zasshi*, *Niigata no Engei*, *Nogyo Gijutsu Taikei*, *Tohoku Nogyo Kenkyu*, Tropical Agricultural Research Series, *Yasai Engei Gijutsu* and numerous other journals of limited distribution.

In general, these 160 research articles and publications can be categorized into seven research areas: agronomy (crop management) (37%), biochemistry (15%), breeding and germplasm (12%), harvesting and processing (12%), statistics and marketing (12%), plant physiology (9%), and plant pathology (3%). A short review of notable papers and research trends in each category follows.

Agronomy

Research on crop management has been summarized by Kono (1986, 1988), Hagiya (1987), Kobayashi (1978), and Sawaji (1971). Production in the cool climate of Hokkaido has been reviewed by Sunada (1986) and Ishioka (1985) and vegetable soybean seed production is reviewed by Ono (1989). Research has focused on the advancement of the growing season by use of transplants, plastic mulches, and vinyl tunnels over the plants (Ono 1988a; Watanabe 1988a,b), determining optimum application of nitrogen (Tamada et al. 1990; Kobayashi et al. 1989; Kikuchi and Hatakeyama 1988), analyzing the effect of plant density on pod color and finding that the more sunlight that directly struck the pods, the darker the pods were at harvest (Chiba et al. 1989), growing vegetable soybean under special cultural conditions such as in the winter in CO_2-enriched greenhouses (see Sato 1983; Sato and Takahashi 1984) and where the water supply is contaminated with seawater (Nukaya et al. 1977, 1981, 1982a,b).

Biochemistry and plant physiology

Several research groups have investigated the relationship between chemical composition and flavor. The earliest research was by Muramatsu (1924) and Saiki et al. (1931); Masuda (1989) reviewed recent research. Generally, consumers liked vegetable soybean that had higher sucrose, glutamic acid, and alanine contents. Konovsky (1990) found that consumers may fall into two groups. Older ones may prefer vegetable soybean with high alanine content and younger consumers may prefer vegetable soybean with high sucrose and low alanine contents. The results are interesting because alanine has a sweet taste, just like sucrose (Kubota 1972).

Researchers have also looked at the developmental changes in sucrose and amino acid content (Masuda 1989), changes in aromatic components of the steam that is produced while boiling vegetable soybean (Sugawara et al. 1988), and two negative components of taste and quality—trypsin inhibitors and lipoxygenase (Masuda 1989, Tanimura et al. 1980, Matoba et al. 1985, Yoshioka 1991).

Breeding and germplasm

In this area, researchers have studied the variation among vegetable soybean and soybean varieties for water absorption, protein content, starch, and sugar content (Akazawa and Sasahara 1988; 1990a,b,c; 1991), looked at isozyme variation among early-maturing soybean and vegetable soybean varieties from Hokkaido, Tohoku, and Kyushu (Abe et al. 1990, 1991; Hirata et al. 1991), analyzed the genetics of the sugar content of vegetable soybean (Uzawa 1986; Uzawa et al. 1987), the pigments (Nagai 1921; Terao and Nakatomi 1929; Yoshikura and Hamaguchi 1969), seeds/pod and leaf shape

(Takahashi 1934), and inheritance in soybeans (Nagai 1926) was completed in Japan. The early research provided the basic information for breeders to develop varieties of soybeans that were superior for consumption as vegetable soybean.

A number of research groups have run variety trials. By far the most extensive trials have been run at the Tokachi Agricultural Experiment Station (1969, 1981, 1988) in Obihiro, Hokkaido. In a more southern location, a variety trial was carried out by Takahashi and Sato (1983) in Kanagawa Prefecture. The earliest published variety trial evaluated 24 varieties in Yamagata Prefecture (Kouda 1934); Suzuki followed up with the publication of a similar evaluation of 19 varieties in 1984. Saito and Osanai (1979), Takai (1989), and annual editions of *New Vegetable Varieties* (*Sosai no Shinhinshu*) published by the Japanese Horticultural Production Research Center (*Nippon Engei Seisan Kenkyujo*) have reviewed in detail characteristics of new or prominent vegetable soybean varieties.

Konovsky et al. (1991) have published the most recent review of the characteristics and pedigrees of the most popular vegetable soybean varieties currently grown in Japan. Their names and pedigrees are presented in Fig. 3 and described below:

Ezomidori Line. GREEN 75—1985 MAFF Registration #715 (earlier maturing mutation of Ezomidori): it has extremely large seeds and pods, especially for such an early-maturing variety, but moderate yields (JHPRC 9:110; MAFF 1990; Takai 1989; JSTA 1987).

Wasemidori Line. SAPPORO-MIDORI—1974 MAFF Trademark #263 (Kogenmidori×Hokuiku 1): it is the most popular variety for fresh market, early production because of its good taste, large seeds (for an early variety), and dark green pods. In spite of its popularity for early production, Sapporo-midori germinates poorly under cool conditions (JHPRC 7:76; Masuda 1989; TAES 1988; JSTA 1987).

Sakhalin Lineage. KITANOSUZU—1986 MAFF Registration #1137 (Toyosuzu×Hakucho): it withstands temperature stress better than other varieties, yields very well, especially in fertile soil, and has dark green pods, but the pod profile is slimmer than Sapporo-midori (Snow Brand Seed Co.; JHPRC 9:102; MAFF 1990; Takai 1989). (Incidentally, Hakucho is an earlier maturing selection from Osodefuri still used for commercial production and as a parent in hybridization programs (Tokita Seed Co.; Masuda 1989; Kono 1986; Nishi 1986).)

Okuhara Line. TENGAMINE—1985 (Okuhara×Shiroge Line): it has high sucrose and glutamic acid content, large seeds, and sparse pubescence, but light green pod color and moderate yields (JHPRC 10:87; Konovsky 1990; JSTA 1987). *Shiroge* is a word that designates any pedigree with white pubescence (Kono 1986; Nishi 1986); in this case, a shiroge variety was crossed with Okuhara to develop a similar variety, but with white rather than brown pubescence.

Tzurunoko-Osodefuri Lineage. KARIKACHI 1, 2, or 3—1976,84,86: (selection from Toya): it combines the best qualities of Tzurunoko and Osodefuri with maturity nearer to Osodefuri and days ahead of Tzurunoko. Karikachi 3 is more disease-resistant than the earlier releases (Tokita Seed Co.; JHPRC 8:95; JSTA 1987). (Tzurunoko is a fall variety that is favored for production of frozen edamame because of its large, two- to three-seeded pods that turn dark green after blanching and freezing, and Osodefuri is noted for its excellent flavor (Masuda 1989; TAES 1988; Kono 1986; Nishi 1986).) A note of caution: this variety was developed by Tokita Seed Co. and first released in 1976; it is not to be confused with a release in 1959 by the Tokachi Agricultural Experiment Station in Hokkaido of a variety of soybean called Karikachi.

Osodefuri Line. FUKURA—1977 (selection from Raicho): it is often used as a research standard (see Chiba et al. 1989; Kiuchi et al. 1989) to compare with new, earlier maturing varieties because of its overall high quality (Kaneko Seed Co.; JSTA 1987). (Shirojishi has a pedigree similar to Fukura, but matures much earlier (Takii Seed Co.).)

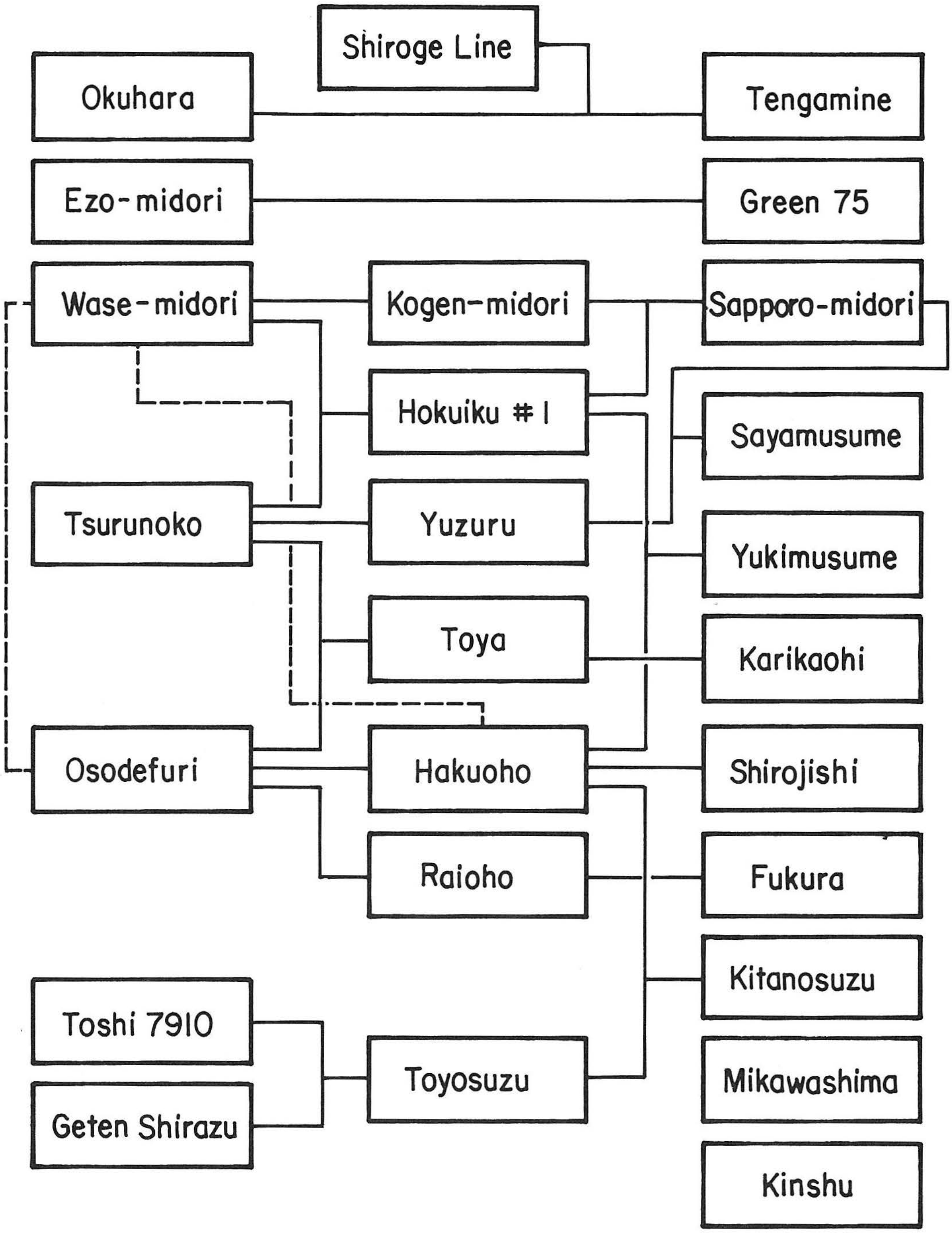

Fig. 3. Pedigrees of popular vegetable soybean varieties currently grown in Japan.

Tzurunoko Line. SAYAMUSUME—awaiting MAFF registration (Sapporomidori × Yuzuru): like its relative, Tzurunoko, it is noted for its many very dark, three-seeded pods and long harvest period, but it matures several days earlier than Tzurunoko (Snow Brand Seed Co.).

Osodefuri-Wasemidori Lineage. YUKIMUSUME—1977 MAFF trademark #322 (Hakucho×Hokuiku 1): it has many branches leading to high yields of fairly large pods and its Osodefuri lineage ensures good flavor; growers consider it the best of the medium-maturing varieties (Snow Brand Seed Co.; JHPRC 7:76; Masuda 1989; TAES 1988; JSTA 1987).

Mikawashima Line. MIKAWASHIMA—public variety (Kanto Land Race): an intermediate edamame variety that produces many three-seeded pods, but is prone to lodging because of its viney growth (NIAR 1990; Masuda 1989; Kono 1986).

Kinshu Line. KINSHU—public variety (Aomori Land Race): a fall edamame that is frequently used as a standard for later maturing varieties because of its overall good quality (Musashino Seed Co.; Snow Brand Seed Co.; Iwate Agricultural Experiment Station; NIAR 1990).

Extensive collection of land races in the Tohoku region of Japan was conducted in the 1950s and resulted in the publication of a report detailing the characteristics of 237 accessions from Iwate Prefecture alone (Ministry of Agriculture and Forestry 1957); many more were collected in Aomori, Akita, Yamagata, Fukushima, and Miyagi Prefectures. Later, Kiuchi et al. (1987), working at the Iwate Agricultural Experiment Station, collected another 400 land races from nearby farmers and evaluated them for simple morphological characteristics. Watanabe and Nagasawa (1990a,b; 1988) focused their research on morphology and biochemistry and compared the chemical composition of soybean land races and several vegetable soybean accessions.

Most of the vegetable soybean germplasm in Japan is distributed between three collections: at the National Institute of Agrobiological Resources in Tsukuba, at the Kariwano Laboratory of the Tohoku National Agricultural Experiment Station in Akita Prefecture, and at the Tokachi Agricultural Experiment Station in Hokkaido (Kaizuma 1976). Samples are available from NIAR at Tsukuba, but difficult to obtain from Kariwano or Tokachi.

Harvesting and processing

Masuda (1989) also reviewed information on postharvest decline in quality and ways to limit deterioration. For example, researchers have studied the sucrose present in vegetable soybean seeds within 24 hours after harvest (Chiba and Yaegashi 1988; Mori et al. 1976a,b; Iwata and Shirahata 1979; Akimoto and Kuroda 1981; Iwata et al. 1982; Fukushima and Takada 1983), the sugar content of hand-harvested pods compared to machine-harvested pods (Abe and Okuda 1986; Abe et al. 1985) and the cooling of pods on sucrose and amino acid content (Matsui et al. 1980).

Statistics and marketing

The statistics cited in the section entitled, *Trends in Production and Demand*, come from three sources—the annual *Statistical Yearbook of the Ministry of Agriculture, Forestry, and Fisheries* (for example, see Ministry of Agriculture, Forestry and Fisheries 1991), the monthly tally of exports and imports and annual summary called *Japan Exports & Imports* published in January by the Japan Tariff Association (for example, see Japan Tariff Association 1991), and statistics published by the Prefectural Departments of Agriculture (for example, see Iwate Prefecture Department of Agriculture 1990, 1989; Yamagata Prefecture Department of Agriculture 1989; Niigata Prefecture Department of Agriculture 1990; Agriculture Hokkaido 1990). In addition, Masuda (1989) gives a succinct summary of current market conditions.

Plant pathology

Very little research has been carried out on diseases in vegetable soybean. Most of the information is gleaned from research on grain soybeans. Kono (1986, 1988) gives a general review; Shimizu and Kimura (1987) review nutritional deficiencies in soybeans and vegetable soybean; and Akai (1988) reviews plant diseases of soybeans including vegetable soybean. A single article by Suwa et al. (1986) reports on experiments to analyze the most effective control of a disease, in this case verticillium wilt in plastic mulched beds.

Research Information

In general, access to information about vegetable soybean research in Japan is restricted to researchers who are fluent in Japanese. Information can even be difficult for native scientists to procure. First, libraries are one of the weakest links in the Japanese research system. Very little government support is given to libraries and very few universities have a centralized library. Most book and journal collections are scattered among labs and departments, and most collections of individual journals are incomplete. Thus, the historical documentation of research is extremely difficult, and nearly impossible for someone outside of Japan. Japanese researchers are under little pressure to publish, so research reports usually emerge slowly or not at all. However, information about current research does flow through the network of researcher affiliations and frequent regional and national meetings.

When we began compiling the bibliography published with this paper, every researcher questioned in Japan said there were no reports available on vegetable soybean research. While 160 reports in 70 years is a very small number, the amount of research completed on vegetable soybean is not well known even in Japan.

Japanese researchers can easily tap Western soybean research through widely distributed abstracts such as Soybean Abstracts, Biological Abstracts, and computer database services such as DIALOG, but very few vegetable soybean reports are indexed in international databases such as AGRIS International. For example, fewer than 10 of the articles in the bibliography showed up on the database searches; most articles were gleaned from *Japanese Agricultural Sciences Index (Nippon Nogaku Bunken Kiji Sakuin)*, an annual Japanese publication available at some libraries. The mentality of restricting access to information and germplasm in Japan even inhibits research in Japan and gives a poor image to the rest of the world.

At the same time, most Western libraries and researchers are seriously at fault for not making a stronger effort to collect and understand Japanese research literature. Often the accomplishments of Japanese scientists go unrecognized for years or decades in the West. The proceedings of this meeting will be welcomed by soybean researchers in many countries and will expand the use of vegetable soybeans to all peoples of the world.

Apparent Research Needs

In spite of all the excellent research on edamame in Japan, the general opinion among older consumers in Japan is that the taste of vegetable soybean has gotten worse as it has been commericalized. As numerous Japanese research reports have shown, the quality of unprocessed vegetable soybean declines rapidly at normal summer temperatures, losing much of its appeal after 24-48 hours, especially for free pods. Thus, while quality in the field is high, much is lost by the time the inefficient transportation and intermediary system delivers it to the consumer. As with most commodities, the application of research results lags far behind research, as do the practical means for that application.

It could be argued that the cooked vegetable soybean peddled by farming women through the streets of Edo over a century ago tasted as good or better than existing products, although the Edo product lacked the improvements made by recent varietal selection. In this situation, more emphasis should be placed on the difficult task of development of improved production, harvesting, processing, transportation and marketing systems, in addition to the research areas discussed below.

Agronomy

The research to date on the relationship between crop management and quality is at best preliminary. No conclusive answers are available to questions like: what is the influence of planting date and density on pod color and seeds/pod? Do vegetable soybean plants respond differently in temperate and tropical environments? What effect does rate and timing of nitrogen application have on seed weight, pod color, and sucrose content? How do different vegetable soybean varieties vary in response to changes in crop management? Can the vegetable soybean stems, leaves, unfilled pods be part of an integrated fodder/ silage system? Can single-seeded pods be shelled for sale as a separate product?

Biochemistry and plant physiology

The most fundamental unanswered question about vegetable soybean is how do vegetable soybean varieties differ from grain soybean varieties? Is there a physiological difference beyond the common distinction made by seed weight? Many theories abound, but there is little evidence to support any of them. Akazawa and Sasahara (1990c) determined that vegetable soybean varieties had higher sugar levels than soybean varieties. This is caused by the higher concentration of abscissic acid (ABA) in large-seeded genotypes and the relationship between ABA, enlarged petiole size, and increased sucrose uptake by the developing seeds (Schussler et al. 1984). Researchers at AVRDC report that vegetable soybean varieties tend to have more podless terminal nodes (S. Shanmugasundaram, AVRDC, pers. comm.) and vegetable soybean varieties are known to be more susceptible to pod shatter; both these facts might also be related to ABA concentration. Are ABA-mediated biochemical pathways and concentrations different between vegetable soybean and soybean?

A second line of research concerns flavor. The relationship between consumer preference for taste and chemical composition of the seeds needs more exact characterization. Are alanine and sucrose the most important? Does consumer preference vary? Do aromatic components like jasmone play a role in flavor? Once we understand the relationships, breeding targets can be developed to enhance the taste of vegetable soybean. Poor flavor is the number one complaint among Japanese consumers (Yamauchi 1990), so work on this question is very important.

Negative flavors and the activity of lipoxygenase at the vegetable soybean stage of development are not well understood. Is their activity great enough to produce beany flavors that detract from the sweet and savory flavor of vegetable soybean? With the development of null alleles for all three lipoxygenase genes, breeders must determine the benefits to be gained from the time-consuming introduction of those genes into vegetable soybean varieties.

Breeding and germplasm

The genetics of protein and oil are well researched (for example, see Kaizuma and Fukui 1972), but very little is known about the genetics and physiology of sucrose production. First, heritabilities need to be reassessed, the genes responsible need to be isolated, and biochemical pathways of utilization clarified. With that information, breeders will be able to develop new, super-sweet varieties of vegetable soybean more easily and those new varieties might have even wider consumer appeal. In addition, basic research on sucrose content would be welcomed among soybean researchers and help them to better understand the general metabolism of the soybean plant.

The second priority for research is the collection and characterization of the remaining soybean and vegetable soybean land races in northern Japan and the eastern coast of the Soviet Union. As agriculture modernizes in these regions, land races are being lost. It is imperative to collect what remains, and characterize it for usefulness to vegetable soybean and soybean breeding programs. The region is best known for its cool climate, and land races collected here have been essential in the development of cold tolerant vegetable soybean and soybean varieties. In addition, accessions already in the Japanese collections at Tokachi and Kariwano need to be made available to researchers around the world.

Harvesting and processing

The most difficult problem facing growers is deciding when to harvest vegetable soybean. What sort of technical information can a grower gather to help decide when to harvest? No easy system exists. Research is needed on using the pod width-seed width ratio, moisture content, sugar content, and pod thickness methods of determining the best harvest date to develop simple technology that all farmers can afford and use.

Second, to control production costs, methods of mechanically harvesting vegetable soybean need to be refined. If harvesters can be developed that do not drop, bruise, or break pods, the technology can replace expensive hand labor.

Plant pathology

Most of the research on vegetable soybean has focused on quality. Little attention has been paid to pests. A future challenge will be to develop vegetable soybean lines that are virus- and disease-resistant. As vegetable soybean production spreads around the world, more pests will be encountered and the demand for resistance will grow. Sometimes the solution may be as simple as crossing a resistant soybean line with a well accepted vegetable soybean line, and then backcrossing to recover the original genotype. However, the peculiar demands for quality of vegetable soybean might force breeders to search for other sources of resistance that do not detract from quality, but at the same time protect the plants from pathogens.

Conclusion

In conclusion, while more research has been conducted on vegetable soybean in Japan than in any other country in the world, significant improvements are needed and many problems remain. Vegetable soybean is a minor crop and has received very little attention from the agricultural research community. However, because it is an easily grown, healthy fast food, it will continue to grow in popularity in Japan and elsewhere. Although crop management practices that produce the best flavor, appearance, and yield of vegetable soybeans vary from location to location because of climate and geography, cooperation among the participants in this workshop can speed the development of a significant information base on the production and processing of vegetable soybean that will be useful to producers around the world. Vegetable soybean researchers need to help this vegetable emerge from isolation in East Asia and become an important vegetable of global significance.

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Bibliography

Abe, I., and Okuda, Y. 1986. Maintaining freshness in machine harvested edamame (*Kikai dakkyo edamame no sendo hoji gijutsu ni kansuru kenkyu*). *Engei Gakkai Taikai Kenkyu Happyo Yoshi* (Horticultural Symposium Abstracts) Spring S61, 466-67.

Abe, I., Okuda, Y., Iwata, T., and Chachin, K. 1985. Maintaining freshness in machine harvested edamame (*Kikai dakkyo edamame no sendo hoji gijutsu ni kansuru kenkyu*). *Engei Gakkai Taikai Kenkyu Happyo Yoshi* (Horticultural Symposium Abstracts) Fall S60, 494-95.

Abe, J., Hirata, T., and Shimamoto, Y. 1990. Isozyme differentiation in native soybean cultivars from different regions of Hokkaido. *Ikushugaku Zasshi* (JJ Breeding) 40 (*Bessatsu* 2), 360-61.

1991. Dimorphism and origin of native soybeans with extremely early maturity in Hokkaido. *Ikushugaku Zasshi* (JJ Breeding) 41 (*Bessatsu* 1), 482-83.

Agriculture Hokkaido. 1990. Hokkaido Vegetable Map (*Hokkaido Yasai Chizu*). *Hokkaido Nogyo Kyodo Kumiai Chuokai and Hokuren Nogyo Kyodo Kumiai Rengokai*, Sapporo.

Agriculture Niigata—Horticulture Division. 1988a. Improving the market for edamame this year (*Kotoshi wa kou susumetai edamame no hanbai taisaku*). *Niigata no Engei* (Niigata Horticulture), 3, 22-23.

1988b. Investigation of edamame production—from a marketing standpoint (*Edamame zukuri sotenken—hanbaimen kara*). *Niigata no Engei* (Niigata Horticulture), 3, 13-16.

1990. Brand names: how to improve edamame this year (*Burando hinmoku: kotoshi kou susumetai—edamame*). *Niigata no Engei* (Niigata Horticulture), 3, 11.

Aichi Prefecture Agricultural Research Center. 1981. Investigations on freezing green vegetables 1: Freezing edamame (*Ryokushoku yasai no toketsu chozo ni kansuru shiken 1: Edamame no toketsu chozo shiken*). *Aichi-ken Nogyo Sogo Kenkyusho Nosanbutsu Ryutsu Shiyo Seisekisho*, S55, 122-123.

Aichi Prefecture Horticultural History Association. 1981. Other beans (*Sono Hoka Mamerui*). *Page* 370 *In*: *Aichi-ken Engei Hattasu Shihen Sankai*, History of Horticulture in Aichi Prefecture: vegetables (*Aichi-ken Engei Hattatsushi: yasaihen*). Aichi Prefecture, Nagoya.

Akai, J. 1988. Soybeans (*Daizu*). *Pages* 108-17 *In*: Kishi, K. (ed.), Plant Diseases in Japan (*Sakumotsu Byogai Jiten*). *Zenkoku Noson Kyoiku Kyokai*, Tokyo.

Akazawa, T., and Sasahara, T. 1988. Genetical studies on the quality of green soybeans 1: Correlations between water absorption characteristics of ripened soybean grains. *Ikushugaku Zasshi* (JJ Breeding) 37 (*Bessatsu* 2), 240-41.

1990a. Differences of water absorption characteristics of ripened seeds of edamame (green soybean) and soybean cultivars. *Ikushugaku Zasshi* (JJ Breeding), 40, 349-59.

1990b. Genetical studies on the quality of green soybeans 2: Varietal difference of seed protein in green soybeans. *Ikushugaku Zasshi* (JJ Breeding) 40 (*Bessatsu* 1), 494-95.

1990c. Genetical studies on the quality of green soybeans 3: Varietal differences of sugar content in green and ordinary soybean seeds. *Ikushugaku Zasshi* (JJ Breeding) 40 (*Bessatsu* 2), 226-27.

1991. Genetical studies on the quality of green soybeans 4: Varietal differences of starch and nitrogen content in green and ordinary soybean seeds with reference to maturing stage. *Ikushugaku Zasshi* (JJ Breeding) 41 (*Bessatsu* 1), 238-39.

Akimoto, K., and Kuroda, S. 1981. Quality of green soybeans packaged in perforated PE/PP film. *Engei Gakkai Zasshi* (JJ Horticulture), 50, 100-07.

Aoba, T. 1956. The special kinds of vegetables in Shonai, Yamagata Prefecture 7) edible soybean, *dadachamame* (*Shonai tokunai sosai 7) dadachamame*). *Yamagata-ken Norin Gakkaiho* (Yamagata Agriculture Symposium), 10, 5-10.

Aoki, H., and Ito, K. 1979. Cooking and Soybeans (*Chori to Daizu*). *Gakken Shoin*, Tokyo.

Banba, H., Tanimura, Y., and Matsukawa, I. 1986. Breeding for resistance to soybean dwarf virus in soybeans. Tropical Agriculture Research Series, 19, 236-46.

Chiba, Y., and Muto, K. 1987. An effective pre-cooling method for vegetables in the small-scale cooling room. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 40, 335-36.

Chiba, Y., and Yaegashi, S. 1988. Quality change of green soybeans after harvest. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 41, 287-88.

Chiba, Y., Yaegashi, S., and Sato, H. 1989. Cultivation method of green soybean 1: Effect of planting density on quality and yield. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 42, 279-80.

Cook, A.K. 1988. The Evolution of Japanese Food Spending Patterns: 1963-1984. Washington State University IMPACT Center Report 26.

Fukushima, T., and Takada, T. 1983. The influence on edamame of excising the leaves and roots (*Ha, ne no setsujo ga edamame no seibun ni oyobosu eikyo*). *Engei Gakkai Taikai Kenkyu Happyo Yoshi* (Horticultural Symposium Abstracts) Fall S58, 474-75.

Furuda, M., and Akegawa, T. 1978. The influence of blanching on frozen edamame varieties (*Reito edamame no hinshu ni oyobosu buranchingu no eikyo*). *Niigata-ken Shokuhin Kenkyu Hokoku* (Niigata Food Research), 15, 9-15.

Furusawa, F. 1984. Zunda mochi. *Page* 206 *In*: F. Furusawa (ed.), Iwate Foods (*Kikisho Iwate no Shokuji*). *Nosangyo Bunka Kyokai*, Tokyo.

Gotoh, K. 1984. Historical review of soybean cultivation in Japan. Tropical Agriculture Research Series, 17, 135-42.

Hagiya, H. 1987. Edamame. *In*: Ito, T. (ed.), Vegetable Crop Management *(Yasai no Saibai Gijutsu). Seibundo Shinkosha*, Tokyo, 424-32.

Hatakeyama, S., and Moichi, S. 1987. Culture of green soybeans in the northern area of Iwate Prefecture 1: The growth and yield traits in different cropping seasons. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 40, 297-98.

Hatakeyama, T. 1988. Hanamaki's new crop—edamame—becomes a major commodity (*Hanbai yasai no shuryoku hinmoku ni seicho suru Hanamaki-shi no tensaku edamame*). *Yasai Engei Gijutsu* (Horticultural Vegetable Production), 11, 63-64.

Hayashi, Y., and Ariyama, H. 1960. Studies on pulses used as food in Japan. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 11, 171-85.

Hirata, T., Abe, J., and Shimamoto, Y. 1991. Isozyme and differentiation in land races of soybeans in Japan. *Ikushugaku Zasshi* (JJ Breeding) 41 (*Bessatsu* 1), 480-81.

Ho, P.T. 1974. The Cradle of the East: an inquiry into the indigenous origins of techniques and ideas of Neolithic and early historic China, 5000-1000BC. University of Chicago, Chicago.

Honda, K. 1987. Compensational response of soybeans to the immature pod injury caused by stink bugs. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 40, 137-38.

Hoshikawa, K. 1983. Soybeans. Volume 7, Page 239 *In*: Kodansha (ed.), Encyclopedia of Japan. *Kodansha* International, Tokyo.

Hoshino, T. 1988. Edamame in Niigata Prefecture (*Niigata no edamame*). *Daizu Geppo* (Soybean Monthly), 153, 10-13.

Hymowitz, T., and Kaizuma, N. 1981. Soybean seed protein electrophoresis profiles from 15 Asian countries or regions: hypotheses on paths of dissemination of soybeans from China. Economic Botany, 35, 10-23.

Hyogo Prefecture Central Agricultural Center. 1988. On the quality and harvest timing of black soybeans used for edamame (*Kurodaizu edamame no shukakuki to hinshitsu ni tsuite*). *Hyogo-ken Chuo Nogyo Gijutsu Senta Ryutsu Shiyo ni Kansuru Shiken Kenkyu Seiseki Gaiyo* S63, 53-54.

Igata, S. 1977. Edamame. *Pages* 148-49 *In*: Igata, S. Research on the History of Cereal Crops (*Nippon Kodai Kokumotsushi no Kenkyu*). *Yoshikawa Kobunkan*, Tokyo.

Ikeda, T. 1989. Recent trends in the importation of perishable vegetables (*Seisen yasai no saikin no yunyu doko*). *Yasai Engei Gijutsu* (Horticultural Vegetable Production) 1, 51.

Imon, S. 1985. Plant fiber in various food groups and its use (*Shokuhin gunbetsu no shokumotsu seni to sono koyo*). *Shoku to Kagaku* (Food and Chemistry), 94, 37-50.

Ishiguro, K. 1985. Edamame. Pages 305-07 *In*: Ishiguro, K. Thoughts on Vegetables (*Yasairo*). *Aichi-ken Keizai Nogyo Kyodo Sogo Rengokai* (Agriculture Aichi), Nagoya.

Ishioka, E. 1985. Edamame. Pages 190-97 *In*: Yakuro, T. Production of Vegetables in Hokkaido (*Hokkaido no Yasai Saibai Gijutsu*). *Nogyo Gijutsu Fukyu Kyokai*, Sapporo.

Ito, T. 1988. Edamame market trends and changes in production (*Edamame no ichiba doko to sanchi e no teigen*). *Yasai Engei Gijutsu* (Horticultural Vegetable Production), 11, 65.

Iwai, R., and Inoue, Y. 1968. Edamame. *In*: *Seibundo Shinkosha* (ed.), New Horticultural Dictionary (*Saishin Engei Daijiten*). *Seibundo Shinkosha*, Tokyo, 758-59.

Iwase, T., Oba, S., Yanagida, M., Tomita, H., Naijo, M., and Higuchi, K. 1983. Cultural method of green soybean for summer and autumn crop. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 33, 239-40.

Iwata, T., and Shirahata, K. 1979. Keeping quality of green soybeans I: the factors concerning post-harvest quality deterioration and the effects of atmosphere and whole plant packaging. *Engei Gakkai Zasshi* (JJ Horticulture), 48, 106-113.

Iwata, T., Sugiura, H., and Shirahata, K. 1982. Keeping quality of green soybeans by whole plant packaging. *Engei Gakkai Zasshi* (JJ Horticulture), 51, 224-30.

Iwate Prefecture Agricultural Experiment Station. 1987. Report on the development of new varieties of edamame (*Edamame shinhinshu ikusei ni kansuru shiken seisekisho*). *Iwate-ken Nogyo Shikenjo*, Takizawa.

Iwate Prefecture Department of Agriculture. 1989. Guide to the Production of Vegetables and Flowers (*Yasai, Kaki Saibai Gijutsu Shishin*). Iwate Prefecture, Morioka.

1990. Grading and Shipping Standards for Produce (*Iwate-ken Seikabutsuto Shukka Kikaku Shido Hikkei*). Iwate Prefecture, Morioka.

Japan Bean Foundation. 1957. Report on Local Ways of Eating Beans and Other Minor Crops in the Tohoku Region (*Tohoku Chiho ni Okeru Mamerui Zakkyoku Ruito no Kyodoshoku Kanko Hokoku*). *Nippon Mamerui Kikin Kyokai*, Tokyo.

1988. Report on the Investigation of the Prefectural Distribution and Production of Minor Beans (*Fukensan Zatsumame Seisan Ryutsu Jittai Chosa Hokokusho*). *Nippon Mamerui Kikin Kyokai*, Tokyo.

Japan External Trade Association. 1983. Frozen and Dried Vegetables, Access to Japan's Import Market. JETRO, 38, 1-20.

Japan Tariff Association. 1991. Japan Exports and Imports. Japan Tariff Association, Tokyo.

Japanese Horticultural Production Research Center (*Nippon Engei Seisan Kenkyujo*). 1990. New Vegetable Varieties (*Sosai no Shinhinshu*). *Seibundo Shinkosha*, Tokyo.

Japanese Science and Technology Bureau. 1984. Standard Table of Food Composition (*Shitei Shokuhin Seibun Hyo*). *Kagaku Gijutsucho*, Tokyo.

Japanese Seed Trade Association. 1987. Vegetable Variety List (*Yasai Hinshu Meikan*). *Nippon Shubyo Kyokai*, Tokyo.

Jussaume, R.A. 1989. Food Consumption in Seattle, Wa. and Kobe, Japan. Washington State University IMPACT Center Report 28.

Kaizuma, N. 1976. Japanese germplasm collections. *In*: Hill, L.D. (ed.), World Soybean Research. Interstate, Danville, 298-305.

Kaizuma, N., and Fukui, J. 1972. Breeding for chemical quality of soybeans in Japan. Tropical Agricultural Research Series, 6, 55-68.

Kajimoto, G., Shibahara, A., and Yamashoji, S. 1982. Changes in the contents and composition of lipids, fatty acids, tocopherols, and sterols in soybean seed during maturation. *Eiyo to Shokuryo* (Food & Nutrition), 35, 345-50.

Kameyama, S. 1988. Expectations for Niigata edamame: report from the Tokyo-Yokohama markets (*Niigata edamame ni kitai suru: Tohama ichiba kara*). *Niigata no Engei* (Niigata Horticulture), 3, 24-28.

Kato, T., Michishita, M., Kurose, S., Inoue, S., and Nakayama, K. 1979. Studies on the physiological role of rutin and its application to vegetable crops V: effect of rutin application on the fruit setting and pod development of green soybean plants. *Kochi Daigaku Gakujitsu Kenkyu Hokoku—nogaku* (Kochi University), 27, 113-122.

Kato, T., Fukushima, T., and Akazawa, T. 1982. Differences in contents of amino acid, sugars, and composition of fatty acids between edamame and normal soybeans. *Engei Gakkai Zasshi* (JJ Horticulture) 51 (*Bessatsu 2*), 537.

Kikuchi, T., and Hatakeyama, S. 1988. Cultivation of green soybeans in the northern area of Iwate Prefecture 2: Effect of nitrogen fertilizer application on green soybeans. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 4, 275-76.

Kitagawa, I., and Yoshikawa, M. 1983. Active components of metabolism in plants (*Shokumotsu no naka no seibutsu kassei busshitsu*). *Kagaku to Seibutsu* (Chemistry & Biology), 21, 224-32.

Kitamura, K., Davies, C.S., Kaizuma, N., and Nielsen, N.C. 1983. Genetic analysis of a null-allele for lipoxygenase-3 in soybean seeds. Crop Science, 23, 924-27.

Kiuchi, Y. 1989. Progress on the development of new varieties of edamame in Iwate Prefecture (*Iwate-ken ni okeru edamame shinhinshu ni ikusei keika*). *Mamerui Saibai Ikushu Kenkyu Tsushin* (Bean Cultivation & Breeding Research), 7, 3-5.

Kiuchi, Y., Ishikawa, H., Nitta, M., and Sasaki, T. 1987. Collection of crop genetic resources and their characteristics in Iwate prefecture 1: Characteristics of local soybean varieties. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 40, 139-140.

Kiuchi, Y., Ishikawa, H., Nitta, M., Sasaki, T., and Sato, T. 1989. New vegetable-type soybean varieties: *Iwamamekei-1*, *Iwamamekei-2*, *Iwamamekei-3*, *Iwamamekei-4*, and *C9*. *Iwate-ken Nogyo Shikenjo Kenkyu Hokoku* (Iwate Prefecture Agricultural Experiment Station), 28, 27-39.

Kiuchi, Y., Ishikawa, H., Nitta, M., Sasaki, T., and Takahashi, Y. 1989. The characteristics of new green soybean varieties, *Iwamamekei-3* and *Iwamamekei-4*. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 42, 277-78.

Kobayashi, N. 1978. Edamame. Pages 246-60 *In*: Ministry of Agriculture, Forestry, and Fisheries (ed.), Handbook of Vegetable Production (*Tokusan Yasai Handobukku*). *Chikyusha*, Tokyo.

Kobayashi, T., Orisaka, M., Miyashita, K., and Chiba, Y. 1989. Cultivation method of green soybean 2: Effects of fertilization and soil management on quality and yield. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 42, 281-82.

Konno, S. 1970. Soybean cultivation in Japan. Japan Agricultural Research Quarterly, 5, 21-27.

1984. Soybean production in Japan. Tropical Agriculture Research Series, 17, 95-102.

Kono, M. 1989. Vegetable soybeans. Pages 413-29 *In*: Nobunkyo (ed.), Encyclopedia of Vegetables and Horticulture. *Nosan Gyoson Bunka Kyokai*, Tokyo.

Kono, S. 1986. Edamame. Pages 195-243 *In*: Tanaka, K., Ishida, E., Kono, S., and Kohata, M. Methods of Bean Production (*Sakukei o Ikasu Mamerui no Tsukurikata*). *Nosangyoson Bunka Kyokai*, Tokyo.

1988. Edamame—basics of production (*Edamame—saibai no kiso*). *Nogyo Gijutsu Taikei—yasai* (Agricultural Production—vegetables), 13, 1-17.

Konovsky, J. 1990. The relationship of consumer preference to the amino acid and sugar content of edamame. *Ikushugaku Zasshi* (JJ Breeding) 40 (*Bessatsu 2*), 228-29.

Konovsky, J., Lumpkin, T.A., Shanmugasundaram, S., and Tsou, T.S.C. 1991. Edamame: the vegetable soybean. Asian Vegetable Research and Development Center, Taiwan. (*In press.*)

Kouda, S. 1934. Edamame production from an economic perspective (*Keizai saibai kara mitaru edamame no saibai*). *Nogyo oyobi Engei* (Agriculture & Horticulture), 9, 705-12.

Kubota, T. 1972. Relationship between chemical structure of sweet substances and their taste (*Amami to kagaku kozo*). *Bioteku* (Biotechnology), 3, 629-35.

Liu, C., and Shanmugasundaram, S. 1982. Frozen vegetable soybean industry in Taiwan. *In*: Ali, M.C., and Siong, L.E. (ed.), Vegetables and Ornamentals in the Tropics. Universiti Pertanian Malaysia, Serdang, 199-212.

Masuda, R. 1989. Frozen vegetables—edamame (*Yasai no reito—edamame*). *Reito* (Refrigeration), 64, 359-76.

Masuda, R., Hashizume, K., and Kaneko, K. 1988. Effect of holding time before freezing on the constituents and the flavor of frozen green soybeans (edamame). *Nippon Shokuhin Kogyo Gakkaishi* (JJ Food Science Technology), 35, 763-70.

Matoba, T., Hidaka, H., Narita, H., Kitamura, K., Kaizuma, N., and Kito, M. 1985. Lipoxygenase-2 isozyme is responsible for generation of *n*-hexanal in soybean homogenate. Journal of Agriculture and Food Chemistry, 33, 852-55.

Matsui, S., Hayashi, K., and Nakamura, M. 1980. Influence of low temperature storage and treatment of some chemicals on changes in the quality of green soybeans. *Gifu Daigaku Nogakubu Kenkyu Hokoku* (Gifu University), 43, 223-31.

Matsui, S., Nakamura, M., Watanabe, E., Ohyabu, T., and Kato, Z. 1981. Effect of mulching on growth and yields of green soybeans. *Gifu Daigaku Nogakubu Kenkyu Hokoku* (Gifu University), 45, 277-88.

Matsumoto, S., and Ohba, T. 1972. Growing techniques of soybeans in Japan. Tropical Agricultural Research Series, 6, 75-86.

Matsumura, S. 1986. A method for advancing early development of edamame with plastic row covers (*Porimaruchi ni yoru edamame shoki seiiku sokushin katei*). *Nippon Dojo Hiryogaku Zasshi* (JJ Soil Fertility), 57, 377-83.

Ministry of Agriculture and Forestry. 1957. Tohoku region (*Tohoku chiho*). *In*: MAF, Varieties of Soybeans in Japan and the Significance of their Distribution (*Nippon ni Okeru Daizu Hinshu to Sono Funpu no Igi*). *Norinsho*, Tokyo, 27-77.

Ministry of Agriculture, Forestry, and Fisheries. 1991. Statistical Yearbook. *Norinsuisansho*, Tokyo.

Mitsubishi Corporation. 1989. Access to Japan's Import Market. Tradescope, 4, 9-16.

Miura, H. 1979. Good taste of the local Obon Festival: *dadachamame*—edamame (*Shonai no Bon no Mijiman: dadachamame—edamame*). *In*: *Noko to Engei Henshubu, Furusato no Yasai—Nippon yasaishi* (Local Vegetables—Japanese Vegetable Magazine). *Seibundo Shinkosha*, Tokyo, 47-49.

Mizuno, S., Tsutchida, H., Kotsukue, N., and Terai, H. 1988. Changes in the quality of processed Tamba region black soybeans (edamame) 1: The change in hydrogen and carbon during processing (*Tamba kurodaizu—edamame—no chozoju no hinshitsu henka 1: Chozoju no tansui kabutsu no shocho*). *Engei Gakkai Taikai Kenkyu Happyo Yoshi* (Horticultural Symposium Abstracts) Spring, S63, 524-25.

Moichi, S., Onodera, H., Ohno, Y., and Sasaki, T. 1983. The cultivation for the advancement of cropping season for green soybeans in the northern area of Iwate Prefecture. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 33, 241-42.

Mori, T., Murai, O., Miyawaki, K., and Ohta, K. 1976a. Relation between the taste of fresh green soybeans and storing condition of the raw green soybeans and processing methods of raw green soybeans (*Reito edamame no fumi to genka no chozo jotai narabi no kako hoho no kankei*). *Kagawa-ken Nogyo Shikenjo Kenkyu Hokoku* (Kagawa Prefecture Agricultural Experiment Station), 28, 83-87.

Mori, T., Kubo, T., Murai, O., Miyawaki, K., and Ohta, K. 1976b. Relation between varieties, their seed-times, and characteristics of raw materials for frozen green soybeans (*Edamame no hinshu oyobi wa shuki to reito yogenka to shite no teisei ni tsuite*). *Kagawa-ken Nogyo Shikenjo Kenkyu Hokoku* (Kagawa Prefecture Agricultural Experiment Station), 28, 79-82.

Mori, Y. 1989. Importing and marketing produce (*Seikabutsu no yunyu to hanbai*). *Yasai Engei Gijutsu* (Horticultural Vegetable Production), 1, 58-62.

Morita, S., and Takaura, Y. 1987. The effect of machine harvesting on the quality of green soybeans. Bulletin of the Osaka Agricultural Research Center, 24, 49-54.

Motomiya, G., and Ito, R. 1972. Domestic production, importation, and utilization of food legumes and research organization in Japan. Tropical Agricultural Research Series, 6, 23-42.

Motoyama, T. 1958. Edamame. *In*: Motoyama, T. (ed.), Encyclopedia of Food and Drink (*Inshoku Jiten*). *Heibonsha*, Tokyo, 69.

Muramatsu, S. 1924. On the Composition of the Soybean. Morioka Imperial College of Agriculture and Forestry Bulletin 7.

Nagai, I. 1921. A genetico-physiological study on the formation of anthocyanin and brown pigments in plants. Tokyo University College of Agriculture Journal, 8, 1-92.

1926. Inheritance in soybean. *Nogyo oyobi Engei* (Agriculture & Horticulture), 1, 14 and 107-08.

Nagamine, K. 1989. Sweet bean paste made from edamame in the Tohoku region: zunda can be made in 30 minutes (*Tohoku chiho oishi meibutsu edamame de tsukuru an: zunda wa sanjupun de dekiagari*). *Seikatsu Benri* (Convenient Life), 6/2, 31-33.

Nagata, T. 1960a. Agronomic studies on the genecological differentiation of soybeans in Japan and the world. Science Reports of Hyogo University of Agriculture, 4, 96-122.

1960b. Studies on the differentiation of soybeans in Japan and the world. Memoirs of the Hyogo University of Agriculture, 3, 63-102.

Nagata, T. 1967. Studies on the significance of indeterminate growth habit in breeding soybeans. *Ikushugaku Zasshi* (JJ Breeding), 17, 25-32 and 131-36.

1968. Studies on the significance of indeterminate growth habit in breeding soybeans. *Ikushugaku Zasshi* (JJ Breeding), 18, 235-40 and 291-98.

1972. Agro-genecological approaches to variety differentiation in soybeans. Tropical Agricultural Research Series, 6, 137-50.

Nakui, T., Masaki, S., and Aihara, T. 1988. The fermentative quality and nutritive value as green soybean stover silage. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 41, 199-200.

National Institute of Agrobiological Resources. 1990. Catolog of Plant Germplasm. *Norinsuisansho*, Tsukuba.

Niigata Prefecture Department of Agriculture. 1990. Niigata Shipping Standards for Fresh Fruits and Vegetables (*Niigata-ken Seikabutsu Shukka Kikaku Kijun*): Niigata Prefecture, Niigata City.

Nishi, S. 1986. Edamame. *In*: Nishi, S. Types of Vegetables and a List of Varieties (*Yasai Shurui Hinshu Meiro*). *Nogyo Gijutsu Kyokai*, Tokyo, 182-186.

Nishigaki, S., and Uekuri, Y. 1981. The effects of varieties and cultural method on growth and yields of green soybean. *Osaka-fu Norin Gijutsu Senta Kenkyu Hokoku* (Osaka Agricultural Technology Center), 18, 1-8.

Nishizawa, T., Kon, K., and Nakajima, K. 1988. Transplanting culture of soybean by rice seedling planter 1: Raising method and transplanting accuracy. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 41, 121-22.

Nukaya, A., Masui, M., and Ishida, A. 1981. Relationships between salt tolerance of green soybeans and calcium sulfate applications in sand culture. *Engei Gakkai Zasshi* (JJ Horticulture), 50, 326-31.

1982a. Salt tolerance of green soybeans as affected by various salinities in sand culture. *Engei Gakkai Zasshi* (JJ Horticulture), 50, 487-96.

1982b. Salt tolerance of green soybeans as affected by various salinities in soil culture. *Engei Gakkai Zasshi* (JJ Horticulture), 51, 62-69.

Nukaya, A., Masui, M., Ishida, A., and Ogura, T. 1977. Salt tolerance of green soybeans. *Engei Gakkai Zasshi* (JJ Horticulture), 46, 18-25.

Numata, A., Sakuyama, K., and Takahashi, R. 1989. Introduction of vegetables for rotational cropping system to upland in cold regions 4: Selection of suitable vegetables and cultivative method for the continued use of field mulched with plastic film succeeding to lettuce in early summer. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 42, 161-62.

Numata, A., Sakuyama, K., Takahashi, R., and Iwadate, S. 1988. Introduction of vegetables for rotational cropping system to upland cold regions 3: Selection of suitable vegetables succeeding to edible burdock grown in deeply plowed field with the trencher. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 41, 147-48.

Ogasawara Subtropical Agriculture Center. 1987. Report on Vegetable Experiments 1986. OSAC, Tokyo.

Ogiwara, S. 1989. Trends in the development of seedling production that increase the quality of field vegetables and potential new crop management methods (*Roji yasai ni kohinshitsuka ni taio suru ikubyo kaihatsu no doko to kore kara no kano gijutsu*). *Yasai Engei Gijutsu* (Horticultural Vegetable Production), 5, 19-22.

Okabe, A., Sakai, S., and Kikuchi, A. 1989. Varietal difference in water absorption of soybean seeds. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 42, 109-10.

Okubo, K. 1988. Dry mouth feel, undesirable components of soybean and behavior of the components on soybean food processing. *Nippon Shokuhin Kogyo Gakkaishi* (JJ Food Science Technology), 35, 866-74.

Ono, N. 1988a. Field production of Kurosaki *chamame* (*Roji saibai—Kurosaki chamame*). *Nogyo Gijutsu Taikei—yasai* (Agricultural Production—vegetables), 13, 1-8.

1988b. Improving the production of edamame this year (*Kotoshi wa kou susumetai edamame no seisan taisaku*). *Niigata no Engei* (Niigata Horticulture), 3, 17-21.

Ono, Y. 1989. Vegetable soybean or edamame in Japanese. *In*: Shinohara, S. (ed./trans.), Vegetable Seed Production Technology of Japan Elucidated with Respective Variety Development Histories and Particulars. Shinohara's Authorized Agricultural Consulting Engineer Office, Tokyo, 201-204.

Osodo, K. 1978. Technology of quality maintenance and storage for vegetables. MAFF Report, 54, 1-39.

Ota, K. 1976a. Vegetable growing in paddy fields converted from rice culture 1: Cropping patterns and varieties in green soybean culture 1. *Nogyo oyobi Engei* (Agriculture & Horticulture), 51, 677-79.

1976b. Vegetable growing in paddy fields converted from rice culture 1: Cropping patterns and varieties in green soybean culture 2. *Nogyo oyobi Engei* (Agriculture & Horticulture), 51, 770-72.

1976c. Vegetable growing in paddy fields converted from rice culture 1: Cropping patterns and varieties in green soybean culture 3. *Nogyo oyobi Engei* (Agriculture & Horticulture), 51, 885-88.

Sagara, K., Abe, H., and Moriya, S. 1988. Influence of water extracts made from some vegetables on the seed germination of other vegetables. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 41, 309-10.

Saiki, T., Higuchi, T., Mitsuyuki, K., and Matsuzawa, K.. 1931. The Chemical Analysis of Food in Japan. Tokyo.

Saio, K. 1984. Dietary pattern and soybean processing in Japan today. Tropical Agriculture Research Series, 17, 153-61.

Saito, M. 1972. Breeding soybeans in Japan. Tropical Agricultural Research Series, 6, 43-54.

Sato, N. 1983. Results of experiments using carbon dioxide for greenhouse production of edamame (*Edamame no shisetsu saibai ni taisuru CO_2 shiyo kekka shiken*). *Kanagawa-ken Engei Shikenjo Kasai Shiken Seisekisho* (Kanagawa Prefecture Horticultural Experiment Station), S58, 24-25.

Sato, N., and Takahashi, M. 1984. Establishment of greenhouse production of edamame (*Edamame no hausu saibai gijutsu kakuritsu shiken*). *Kanagawa-ken Engei Shikenjo Kasai Shiken Seisekisho* (Kanagawa Prefecture Horticultural Experiment Station), S59, 58-59.

Sawada, Y. 1988. Expectations for Niigata edamame: report from the Tokyo-Yokohama markets (*Niigata edamame ni kitai suru: Tohama ichiba kara*). *Niigata no Engei* (Niigata Horticulture), 3, 29-30.

Sawaji, N. 1971. Edamame. *In*: Inako, Y., Serisawa, M., and Sawaji, N. Peas, Fava Beans, Green Beans, Edamame, and Sweet Corn (*Endo, Soramame, Ingenmame, Edamame, Suitokon*). *Ie No Hikari Kyokai*, Tokyo, 128-169.

Schussler, J.R., Brenner, M.L., and Brun, W.A. 1984. Abscissic acid and its relationship to seed filling in soybeans. Plant Physiology, 76, 301-06.

Shimizu, T., and Kimura, Y. 1987. Nutritional diagnosis based on deficiency and excess symptoms on crops 3: Deficiency and excess symptoms on soybean. *Nippon Dojo Hiryogaku Zasshi* (JJ Soil Fertility), 58, 226-29.

Shiotani, T. 1985. Production of edamame for fall harvest (*Aki dori edamame no saibai*). *Kurashi to Nogyo* (Life & Agriculture), 9, 24-26.

Shurtleff, W., and Aoyagi, A. 1991. Bibliography of Fresh Green Soybeans. Soyfoods Center, Lafayette.

1991. History of fresh green soybeans and vegetable-type soybeans. Chapter 22 *In*: Shurtleff, W., and Aoyagi, A. History of Soybeans and Soyfoods. Soyfoods Center, Lafayette. (*In press.*)

Sugawara, E., Ito, T., Odagiri, S., Kubota, K., and Kobayashi, A. 1988. Changes in aroma components of green soybeans with maturity. *Nippon Nogei Kagaku Kaishi* (Agricultural & Horticultural Science), 62, 149-55.

Sunada, K. 1979. Varietal improvement (*Hinshu kairyo no ayumi*). *In*: Saito, M., and Osanai, S. (ed.), All Varieties (Hinshu no Subete). Hokkaido Kyodo Kumiai Tsushinsha, Sapporo, 165-194.

1986. Edamame production (*Edamame saibai ni tsuite*). *In*: Sunada, K. Methods of Bean Production in Hokkaido (*Hokkaido no Mame Saku Gijutsu*). *Nogyo Gijutsu Fukyu Kyokai*, Sapporo, 138-140.

Suwa, S., Hayashi, N., Iwasaki, E., Kenmochi, S., Sudo, Y., and Hayashi, S. 1986. Chemical control of verticillium wilt of vegetable soybean by chloropicrin injection into the plastic-mulched ridge (Edamame saibai ni okeru ichobyo no kurorupikurinzai muruchi unenai shori ni yoru bojo). Kanto Tosan Byogaichu Kenkyukai Nenho (Kanto Disease & Pest Research Group), 33, 64-65.

Suzuki, H. 1984. Varieties and production of edamame in Yamagata Prefecture (*Yamagata-ken ni okeru edamame no hinshu to saibai*). *Daizu Geppo* (Soybean Monthly), 109, 36-39.

Suzuki, K. 1984. Production of edamame in Chiba Prefecture (*Chiba no edamame saibai*). *Daizu Geppo* (Soybean Monthly), 110, 23-26.

1988. Investigation of edamame production—from a crop management perspective (Edamame zukuri sotenken—seisanmen kara). Niigata no Engei (Niigata Horticulture), 3, 11-12.

Suzuki, K., and Yahiki, T. 1990. Effects of long day treatment during the period of raising seedlings on growth and yields of green soybeans after transplanting 2: Effect of the length of light period and the starting age of seedlings. Bulletin of the Chiba Agriculture Experiment Station, 32, 123-29.

Suzuki, K., Yashiki, R., and Takeuchi, E. 1985. The influence of long days during the seedling stage on edamame post-transplant development and yields 1: The results of seedling size and long days (*Edamame no ikubyo kikan ni okeru chojitsu shori ga ishokugo no seiiku, shuryo ni oyobosu eikyo 1: Nae no daisho to chojitsu shori no kekka*). *Chiba-ken Nogyo Shikenjo Kenkyu Hokoku* (Chiba Prefecture Agricultural Experiment Station), 26, 39-46.

Suzuki, T., Yasui, A., Koizumi, H., and Tsutsumi, C. 1987. Application of hydrochloric acid extraction procedure to determination of metal elements in soybean, green soybean, and roasted soybean flour by atomic absorption spectrophotometry. *Nippon Shokuhin Kogyo Gakkaishi* (JJ Food Science Technology), 34, 185-89.

Takahashi, M., and Sato, N. 1983. Edamame variety trial (*Edamame hinshu hikaku shiken*). *Kanagawa-ken Engei Shikenjo Kasai Shiken Seisekisho* (Kanagawa Prefecture Agricultural Experiment Station), S58, 71-72.

Takahashi, N. 1934. Linkage relation between the genes for the forms of leaves and the number of seeds per pod of soybeans. *Idenshigaku Zasshi* (JJ Genetics), 9, 208-25.

Takai, R. 1977. Edamame. *In*: Shimizu, S. (ed.), Encyclopedia of Vegetable Horticulture (Yasai Engei Daijiten). Yokendo, Tokyo, 1002-1006.

1989. Edamame. *In*: Takane, M. (ed.), Sources of Plant Germplasm (*Shokumotsu Idenshi Genshusei*). *Kodansha*, Tokyo, 2, 805-06.

Tamada, Y., Orisaka,. M., Miyashita, K., Ohno, Y., Kiuchi, T., and Shinke, H. 1990. Traits of nitrogen release from coating nitrogen fertilizers and cultivation technique without topdressing for upland crops 1: Application effects of coating nitrogen fertilizers for green soybean and sweet corn. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 43, 127-28.

Tanimura, W., Kamoi, I., and Obara, T.. 1980. Distribution of trypsin inhibitors in green soybean (edamame) during cultivation. *Nippon Shokuhin Kogyo Gakkaishi* (JJ Food Science Technology), 27, 245-51.

Terao, H., and Nakatomi, S. 1929. On the inheritance of chlorophyll colorations of cotyledons and seed-coats in the soybean. *Idenshigaku Zasshi* (JJ Genetics), 4, 64-80.

Tohoku Agricultural Experiment Station. 1990. Records of 1988 Cold Damage in Tohoku and Kanto (*Tohoku, Kanto Tosan Chiiki ni Okeru Showa 63 Nen Reigai no Kiroku*). *Norinsuisansho*, Morioka.

Tokachi Agricultural Experiment Station. 1969. Results of Soybean Trials (*Daizu ni Kansuru Shiken Seisekishu*). *Tokachi Nogyo Shikenjo*, Obihiro.

1981. Variety trials of edamame (*Edamame hinshu hikaku shiken*). *In*: TAES, Report on Research. *Tokachi Nogyo Shikenjo*, Obihiro, 145-154.

1988. The Pedigrees and Special Characteristics of Soybean Collection at Tokachi Agricultural Experiment Station (*Daizu Hozon Hinshu, Keito no Raishi oyobi Tokusei*). *Tokachi Nogyo Shikenjo*, Obihiro.

Tomita, H., and Yanagida, M. 1982. Freshness retention of vegetables by precooling 1: Effects of delayed precooling and storage temperature on qualities of asparagus, green soybean, and Italian broccoli. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 31, 267-68.

Torigoe, Y., Inoue, Y., Nakamura, T., Shiraiwa, T., and Kurihara, H. 1982. Production research on indigenous beans in the Tamba district 1: Geographical distribution of Tamba Kurodaizu (a soybean cultivar) and Tamba Dainagon azuki and their cultural practices. Report of the Society of Crop Science and Breeding—Kinki District, 27, 12-16.

Tsuchiya, K. 1984. Information on edamame (Edamame no mame chishiki). Daizu Geppo (Soybean Monthly), 109, 27-35.

Uzawa, H. 1986. Genetic Analysis of Edamame Sugar Content (Edamame no Toseibun ni Kansuru Idenikushugakuteki Kenkyu). Iwate University Master's Thesis, Morioka.

Uzawa, H., Kitamura, K., and Kaizuma, N. 1987. Studies on the sugar content in green soybeans—characterization and inheritance of high sugar content in *dadachamame*. *Ikushugaku Zasshi* (JJ Breeding) 37 (*Bessatsu* 1), 326-27.

Vegetable Experiment Station. 1980. Soybeans, Edamame (*Daizu, Edamame*). *In*: *Yasai Shikenjo*, Local Varieties of Vegetables (*Yasai no Chiho Hinshu*). *Yasai Shikenjo*, Tokyo, 70-75.

Watanabe, I., and Nagasawa, T. 1988. Variation in chemical composition of soybean seeds among genetic resources. *Tohoku Nogyo Kenkyu* (Tohoku Agricultural Research), 41, 105-06.

1990a. Appearance and chemical composition of soybean seeds in germplasm collection of Japan I: Frequency distribution of grain size, seed coat colour, hilum colour and content of chemical components, with special reference to collection site. *Nippon Sakumotsu Gakkai Kiji* (JJ Crop Science), 59, 649-60.

1990b. Appearance and chemical composition of soybean seeds in germplasm collection of Japan II: Correlation among protein, lipid, and carbohydrate percentage. *Nippon Sakumotsu Gakkai Kiji* (JJ Crop Science), 59, 661-66.

Watanabe, M. 1988a. Crop management points for use of plastic bed covers and tunnels for edamame in Chiba Prefecture (*Chiba-ken ni okeru edamame no maruchi, tonneru saibai gijutsu no pointo*). *Yasai Engei Gijutsu* (Horticultural Vegetable Production), 11, 60-62.

1988b. Tunnel production of Sapporo-midori (Tunneru saibai—Sapporo-midori). Nogyo Gijutsu Taikei—yasai (Agricultural Production—vegetables), 13, 1-8.

Watanabe, S. 1988. Brand names: vital points for this month's work—edamame (*Burando hinmoku: kongetsu no sagyo kandokoro—edamame*). *Niigata no Engei* (Niigata Horticulture), 3, 46-47.

Watanabe, S., and Daizen, R. 1988. Rotation systems for edamame production (*Edamame sanchi ni okeru rinsaku taikei*). *Niigata no Engei* (Niigata Horticulture), 3, 31-34.

Yamagata Prefecture Department of Agriculture. 1989. Promoting Fruits and Vegetables (*Kasairui Shinko Shihyo*). Yamagata Prefecture, Yamagata.

Yamashita, F. 1988. Crop management points when switching to edamame production (*Tensaku edamame saibai gijutsu no pointo*). *Yasai Engei Gijutsu* (Horticultural Vegetable Production), 11, 56-58.

Yamauchi, K. 1990. Travels to Study Riddles: edamame (*Nozogaku no Tabi: edamame*). 27 July TV Mook, NTV/ YTV, Tokyo.

Yoshikura, K., and Hamaguchi, Y. 1969. Anthocyanins of black soybeans. *Shokuhin Eiyo Zasshi* (JJ Food Nutrition), 22, 15-18.

Yoshioka, Y. 1991. Method developed to eliminate smell from soybean products. Japan Agroinfo Newsletter, 8(5), 7.

Summary of Discussion and Recommendations

Production

The problem areas identified include:

Short-term

1. Production costs of mechanization
2. Seed Production

Medium-term

1. Cultural management for yield quantity and quality
2. Varietal development for yield quantity and quality
3. Pest and disease resistance goals

Long-term

1. Sustainability
2. Plant architecture
3. Biotechnology and quality

Research needs for vegetable soybean production were discussed, taking into account the constraints and needs of grain soybean. Recommendations for resolving the issues include the following:

1. Need to develop faster mechanical harvesting methods: The imported harvesting machine being used in Taiwan at present and the depodding machine being used in Japan could be combined to develop a machine that can hasten harvesting and which could result in minimal field losses and damage to separated pods. This should include a package of technologies on crop management practices for the efficient use of the new harvester. In the meantime, improvements in the depodding machine available in Taiwan are needed if it is to be used as a stop-gap technology before the improved harvester is developed.

2. Need to confirm the quality benefits of smaller-seeded vegetable soybean from the utilization point of view: A corollary to this is the need for alternatives to cold storage and low relative humidity and storage of vegetable soybean seeds where facilities or techniques are not available.

3. Need to determine precise fertilizer regimes for vegetable soybean, depending on expected yield levels, soil fertility tests, soil type, climate and season: Cost-benefit studies on fertilizer application must be done, taking into consideration higher yield and inputs for improving quality.

Cropping systems research should have a high profitability as the key objective but must be consistent with sustainability issues. Rice-vegetable soybean rotation cropping systems should be developed to maintain a reliable standard against which buildup of pests and diseases can be measured. The introduction of vegetable soybean as an inter or relay crop in low-input systems should be studied.

Likewise, the contribution of vegetable soybean waste to soil fertility maintenance should be evaluated.

Practices that will extend the period over which pods may be harvested should also be studied.

4. Need to breed (where applicable use biotechnology) for:

   - adaptability to mechanical harvesting (without sacrificing quality);
   - resistance to pests and diseases, especially downy mildew and bacterial pustule; rust can be controlled chemically;
   - non or neutral flavors and improvements in taste, e.g. sweetness, through modifications of biochemical pathways;
   - nonshattering characteristics;
   - specific locational adaptation, particularly that governed by temperature and photoperiod; and
   - tolerance to sunscald.

Also, uniform sets of vegetable soybean varieties should be sent to interested countries for evaluation of regional requirements. This information will help guide selection for particular tests undertaken at AVRDC.

The possibility to drastically improve plant architecture for mechanical harvesting should be considered.

One aim should be to increase the harvest index for summer-adapted varieties of vegetable soybean.

Processing and Marketing

The potentials, constraints and research needs for three identified markets were discussed. The markets identified include:

(1) Foreign (Japan, USA and Europe)

(2) Domestic

(3) Developing countries

Potentials of markets

The Japanese market is seen as stable, while the US and European markets are seen as having high potential for the utilization of vegetable soybean as a bean or vegetable, and not as a snack food.

Vegetable soybean is traditionally included in the Chinese diet so the domestic market presents attractive possibilities for both fresh and frozen beans (seeds) and pods. Taiwan grows vegetable soybean mainly for export and thus production is year-round.

In developing countries, vegetable soybean has not been fully accepted yet, although some have histories of vegetable soybean consumption. There is more potential for the product in countries with large Asian communities or populations.

Constraints in markets

In the foreign market, the following problems were identified: delayed processing, overmaturity and existing consumer biases (fresh is always better).

Meanwhile, in Japan and Taiwan, there is a need for more information on consumer preferences and needs, particularly for shelled beans.

In developing countries, there is also a need to explore acceptance of vegetable soybean, especially in areas suffering from nutritional deficiencies.

Research needs

To meet demand for vegetable soybean in foreign markets, more emphasis should be placed on shifting from frozen to fresh vegetable soybean. Refrigerated storage rather than freezing should also be studied. Likewise, a survey on market preferences should be undertaken.

In Taiwan, there is need for research on new processing methods and preparation for convenience, particularly for shelled beans.

In developing countries, focus should be on diversification of uses and improving quality standards for vegetable soybean products

Recommendations

1. Conduct social and biological research that will more clearly define the concept of quality in vegetable soybean. Specifically:

   - Survey consumer taste preferences of the Japanese and other markets;
   - Define biochemical parameters of quality;
   - Evaluate and standardize research methods;
   - Conduct research on environmental influences on quality.

2. Conduct research on postharvest handling and processing technology to improve the quality of vegetable soybean. Specifically, research on the following is needed:

   - improvement of cooling (storage) technology;
   - development of quality-stable varieties;
   - development of products for convenience use, e.g. prepackaged "microwaveable" vegetable;
   - diversification of products from vegetable soybeans, e.g. baby food, noodles, tofu, candies;
   - methodology for harvest time determination;

- improvement of harvesting, packaging and transportation methods.

3. Promote international cooperation, information and technology exchange and sharing by:

    - joint research projects;
    - publication of newsletters, annotated bibliographies, literature reviews, databases and translations;
    - training and workshops; international workshops should be held regularly to keep vegetable soybean researchers up to date on developments in the field;
    - gathering of worldwide market information and statistics;
    - information campaigns on advantages of using vegetable soybean.

Closing Remarks

Emil Q. Javier, Director General
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Allow me to join Dr. Shui-Ho Cheng of the ROC Council of Agriculture and Dr. Wu Yu-Long of the Kaohsiung DAIS in thanking all of the participants and speakers for their very useful inputs during this workshop. The workshop papers, the discussions and the recommendations will provide very important directions for future research and training and vegetable industry development, not only in Northeast Asian countries where the vegetable soybean industry is already advanced, but also in the developing countries where we are confident vegetable soybean will find a useful niche. As has been pointed out in the paper presentations, vegetable soybean can make a very valuable direct contribution to alleviating malnutrition with its adequate levels of protein, calories, vitamins and minerals. Versatility in cropping systems, high farmer incomes, contribution to soil fertility and provision of livestock fodder are additional benefits.

We note with considerable interest your recommendations on production requirements which were conveniently organized into short, medium and long-term needs. The mechanization requirements for harvesting and depodding I am sure will continue to be addressed by the appropriate institutions in Japan and Taiwan which some of you represent.

At AVRDC we will try to find suitable partners with whom we can work on such areas as varietal improvement, proper cultural management for yield and quality and integrated control of pests and diseases. We hope you will continue to make your personal and institutional contributions to these research concerns.

As a fresh product, vegetable soybean needs to be handled properly to maintain freshness, appearance, eating and nutritional quality. The group's recommendations on processing and marketing recognized three kinds of markets—the developed country market in Japan and potentially in the US and Europe, the Taiwan domestic market, and the local markets in the developing countries. Each of these markets has certain unique requirements that must be recognized. The requirements of the fresh or frozen pod market are being looked into but there is a huge potential for shelled fresh or frozen beans which requires attention. For the developing countries the big hurdle apparently is converting passive acceptance of the product into active acceptance.

Vegetable soybean, or "edamame" in Japan, is an old product in East Asia, with great potential to be a new food habit in the rest of the world. Therefore, even as you conduct your activities to meet your respective national needs, please be mindful of this unique opportunity to develop and contribute something novel to world food and agriculture, particularly in the developing countries. We at AVRDC are very excited about this great opportunity and privilege.

Finally I would like to thank all members of the Organizing Committee and of the Local Arrangements Committee for the superb logistics and memorable setting for the meeting.

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