Performance of vegetable soybean cultivars under organic crop management system

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ABSTRACT
The objective of this study was to evaluate growth and yield performance of vegetable soybean (*Glycine max)* cultivars under organic crop management practices. Four cultivars: Kaohsiung No. 6 (KS 6), Kaohsiung No. 9 (KS 9), Tainan ASVEG No. 2 (TNAV 2), and Japan aromatic flavor variety Cha-mame were grown in spring and fall seasons in organic experimental farm at AVRDC – The World Vegetable Center in 2006-2007. Organic crop management practices consisted of *rhizobium* seed inoculation, application of balanced solid and liquid organic fertilizer, integrated pest management involving sex pheromone, yellow and blue sticky paper traps, and bio-pesticide sprays (Neem and Bt); and bio-agents (*Trichoderma* spp., *Bacillus subtilis* and. *Streptomyces* spp. for fungal disease management. Yield performance showed that TNAV 2 produced the highest total pod yield, followed by KS 9 and Cha-mame. However, differences were not significant. TNAV 2 matured late whereas Cha-mame matured early. Over three growing seasons, Cha-mame produced the highest graded pod yield, followed by TNAV 2 and KS 9. This study indicates that both vegetable soybean cultivars Cha-mame and TNAV 2 have greater yield potential than other cultivars when produced under organic farming system.

Keywords
Vegetable soybean, organic farming, integrated pest management, high-value vegetables.

INTRODUCTION
Vegetable soybean (*Glycine max* L. Merrill) is an important crop and source of dietary protein in Southeast Asia (Lumpkin et al. 1992; Konovsky et al. 1994; Mentreddy et al. 2002). The potential biomass yield of vegetable soybean can reach as high as 40 t/ha, consisting of 10 tons of marketable green pods and 30 tons of plant residue that can enrich the soil or feed animals (Shanmugasundaram and Yan 2004). Vegetable soybean is the number one processed frozen food in Taiwan for export market. It has become one of the most important cash crops in Taiwan (Lin and Cheng 2001; Ma et al. 2008). Frozen vegetable soybean imports into US increased from about 300 to 500 t per year in 1980s to about 10,000 t in 2000 (Lin 2001). Taiwan and China are major suppliers of frozen vegetable soybean to the United States. The increasing popularity of soybean as a nutraceutical is currently driving the demand for this vegetable (Lin 2001; Mentreddy et al. 2002). Green pods and products made out of fresh seed are in great demand in most Asian countries, particularly Japan (Lumpkin and Konovsky 1991; Shanmugasundaram 2001).

Lack of suitable cultivars is one of the factors limiting vegetable soybean production in Southeast Asia. Most cultivars of Japanese origin appeared to be suitable for production in Southeast Asia. The Japanese classify soybeans as summer or fall types (Kono 1986). Most cultivars are temperature-sensitive, summer types; only a few are day-length sensitive, fall types. Summer types are planted in the spring and harvested immature after 75-100 days, while fall types are planted in early summer and take 105 days or more. Lingxiao and Kyei-Boahen (2007) evaluated 27 vegetable soybean cultivars and found that cultivars varied from maturity group III to VII. The late-maturing varieties were generally taller, had more nodes/plant, pods/plant, and fresh green pod yield at R6 stage (full seed) than the early-maturing varieties. Konovsky et al (1994) described differences in horticultural traits of some cultivars from Japan and China. Carter and Shanmugasundaram (1993) have compiled a list of vegetable soybean cultivars grown in Japan and Taiwan. AGS 292 a pure line selection was found to be relatively less sensitive to photoperiod and temperature.

Cultivars that produce high pod yields and also high amount of biomass have been developed through breeding at AVRDC – The World Vegetable Center and Taiwan District Agricultural Improvement Stations in Kaohsiung and Tainan. For example, cultivar "Kaohsiung 7" was selected at Kaoshiung District Agricultural Research and Extension Station (KDARES), Taiwan with excellent characteristics including higher yields and better adaptability, larger fresh pod, higher pod set for mechanical harvest, and larger black seed (Chou and Cheng 2002). These cultivars serve dual purposes of pod production and as a green manure crop to replenish soil nutrient levels including nitrogen, soil organic matter and improve soil structure and sustainability (Shanmugasundaram 2001). Due to their short duration (99 to 120 days), vegetable soybeans fit well into existing crop rotation patterns. Dual purpose varieties serve as main summer crop and enable farmers to turn in green crop residue as green manure before planting crops next spring (Shanmugasundaram and Yan 2004). AVRDC in cooperation with KDARES also succeeded in developing and releasing three vegetable soybean varieties for export to Japan, namely Kaohsiung #1, 2, and 3 (Shanmugasundaran et al 1991).

Most of the high yielding vegetable soybean cultivars have been produced under conventional method of cultivation using chemical fertilizers and pesticides. Pesticide residue may hinder the export potential of vegetable soybean especially in countries where strict quality standards are imposed (Srinivasan et al 2009) Studies on the performance of vegetable soybean cultivars under organic crop management system are limited. Ideal and suitable cultivars for organic vegetable soybean production in Southeast Asia should be high yielding (total and graded pods), resistant to insect pests and diseases, early maturing, less sensitive to photoperiod, adapted for growing all year round (spring, summer and autumn seasons), high biomass for green manure, large pod and seed size, high nutritional quality and good storability. For export market requirements, Lai et al (2004) suggested that vegetable soybean should have 100-dry seed rate of 30 g or more, two or more seeds per pod, gray pubescence on pod, short cooking time, easy-to-squeeze pod texture after cooking, and slightly sweet taste.

Increasing concern about environmental quality, human health, and safer agricultural products has led to the development of organic vegetable soybean production in Taiwan and Southeast Asia (Ma et al. 2008). Development of cultivation technologies and expansion of export markets for organic vegetable soybean will be a challenge for sustainable development of vegetable soybean enterprise. The objectives of this study were to: 1) determine growth and yield performance of vegetable soybean cultivars under organic management practices; and 2) identify vegetable soybean cultivars that are suitable for organic production system.

MATERIALS AND METHODS

The field trials were established at AVRDC Organic Field during the dry season of 2006 and 2007. The surface soil structure is silty loam with a pH range of 7.2 and 7.8. The field trials were laid out using a randomized complete block design with three replications. The experimental treatments were the four vegetable soybean cultivars (Cha-name, KS 6, KS 9 and TNAV 2). Figures 1 to 4 show the features of each cultivar. Cha-mame is a Japanese fragrant (aromatic) cultivar with taro flavor and high in sugar content (sweetness). It has brown seed and white flower and matures early. KS 6 is a cultivar developed at KDARES, Taiwan. It matures in 73 days with high graded pod yield. KS 9 is also developed from KDARES. It is high yielding in graded pods with potential yields of 9-10 t/ha). It has good flavor and taste, but seeds are harder than other cultivars. TNAV 2 is developed from Tainan District Agricultural Improvement Station, Taiwan. It matures in 85 days during spring planting and 72 days during fall planting. Pods are large and green with good flavor and taste. It is also resistant to downy and powdery mildew disease.

The cultivars were grown in plots consisting of four beds measuring 1 m wide by 3 m long. The beds were spaced by 50-cm furrows. Three seeds were sown per hill and then thinned down to two seedlings per hill. Seeds were sown in double rows 12 cm apart. Row spacing between double rows was 35 cm with a plant population equivalent to 33,333 plants per hectare.

Organic crop management practices consisted of rhizobium seed inoculation, application of balanced solid and liquid organic fertilizer. Plastic mulching combined with solarization was used to control soil-borne diseases as well as weeds. Bio-agents *Trichoderma harzianum* T2 strain (100 X) and *Bacillus subtilis* strains Y1336 (500X) and WG6-14 (100X) were tested to control soil-borne diseases at seedling stage and other diseases at later growing stages. Other integrated pest management strategies involved sex pheromone, yellow and blue sticky paper traps, and bio-pesticide sprays (Neem and Bt). Plots were frequently furrow-irrigated to maintain soil moisture at field capacity. Data were collected on total and graded pod yield, days from planting to harvest and observations on incidence of pests and diseases.

Standards for graded pods

Vegetable soybean is actually grain soybean harvested at R6 stage when the pods are still green but fully developed. The seeds of vegetable soybeans are commonly larger, sweeter and much tender than grain soybean. Export standard for graded pods are green pods without disease and pest damage and contain two or more seeds per pod. Pod size is 1.3 cm in width and 4.5 cm in length. A 500-g fresh sample contains about 150-170 pods. Other quality standards include gray pubescence, short cooking time, easy to squeeze after cooking and sweet taste.

RESULTS AND DISCUSSION

Total pod yield

Differences in total pod yield were significant ($P \leq 0.05$) among cultivars in all cropping seasons (spring and autumn 2006 and spring 2007 (Table 1). In spring 2006, cultivar TNAV 2 produced the highest total pod yield followed by KS 9. Cultivar Kaohsiung No. 6 produced the lowest total pod yield. In autumn 2006 growing season, TNAV 2 maintained the highest yield, but was not significantly ($P \geq 0.05$) different from cultivars Cha-mame, KS 6 and KS 9 (Table 1). In the spring of 2007, cultivars Cha-mame, TNAV 2 and KS 9 significantly ($P \leq 0.05$) outyielded cultivar KS 6. Small yield differences were obtained between Cha-mame, TNAV 2 and KS 9 in spring 2007, but TNAV 2 maintained as the highest yielder.

Over three growing seasons mean total pod yield was similar between cultivars Cha-mame and KS 9. In general, mean total pod yield was higher in spring than in autumn planting. Low temperature during the later part of the autumn season can reduce pod size and filling that may have contributed to lower yield compared to summer planting. This result is consistent with previous reports where yield is higher in spring than autumn planting (Sundar et al. 2004). The higher yield of TNAV 2 can be attributed to its longer growing period than other cultivars. Cultivar Cha-mame was the shortest in terms of growing period. Cha-mame a fragrant variety matured the earliest in both spring and autumn trials.


Cha-mame


Kaohsiung No. 6


Kaohsiung No. 9


Tainan ASVEG-2

Table 1. Total pod yield of vegetable soybean cultivars grown under organic management system. AVRDC, Taiwan.

Cultivar	Total pod yield (t/ha)			
	SP-2006	AU-2006	SP-2007	Mean
Cha-mame	12.5 ab	9.7 a	10.8 a	11.0
Kaohsiung No. 6	11.8 b	7.1 b	8.5 b	9.1
Kaohsiung No. 9	13 .6 a	9.2 a	10.3 a	11.0
Tainan ASVEG 2	14.0 a	10.4 a	11.2 a	11.9
Mean	12.9	9.1	10.2	

Mean separation in columns by Tukey's Test, P<0.05
SP = spring, AU = autumn

Graded pod yield

Graded pod yields of cultivars were almost similar in spring 2006 (Table 2) and differences were not significant (*P≥0.05*). Significant differences in graded pod yield were observed among cultivars in autumn 2006 and summer 2007 planting. Cultivar Cha-mame produced the highest graded pod yield in both seasons (autumn 2006 and spring 2007). However, its yield was not significantly (*P≥0.05*) different with KS 9 and TNAV 2 in autumn 2006 (Table 2). In spring 2007 both cultivars Cha-mame and TNAV 2 significantly outyielded KS 6 and KS 9 As with total pod yield, similar results were obtained with graded pod yield where average yield was higher in spring than in autumn planting (Table 2).

Table 2. Graded pod yield of vegetable soybean grown under organic management system. AVRDC, Taiwan

Cultivar	Graded pod yield (t/ha)			
	SP-2006	AU-2006	SP-2007	Mean
Cha-mame	8.3 a	5.9 a	6.3 a	6.3
Kaohsiung No. 6	7.6 a	4.5 b	4.8 b	5.6
Kaohsiung No. 9	7.6 a	5.2 ab	5.2 b	6.0
Tainan ASVEG 2	8.3 a	5.9 a	6.3 a	6.8
Mean	7.9	5.4	5.7	

Mean separation in columns by Tukey's Test, P<0.05
SP = spring, AU = autumn

Among cultivars, Cha-name and KS 6 have higher percent graded pod yield than KS 9 and TNAV 2 (Table 3). Graded pod yield of Cha-name and KS 6 reached more than 60% in spring and autumn plantings of 2006.

Table 3. Percent graded pod of vegetable soybean grown under organic management system. AVRDC, Taiwan.

Cultivar	Graded pod (%)			
	SP-2006	AU-2006	SP-2007	Mean
Cha-mame	66.4	60.8	58.3	61.8
Kaohsiung No. 6	64.4	63.3	56.5	61.4
Kaohsiung No. 9	55.9	56.5	50.5	54.3
Tainan ASVEG 2	59.3	56.7	56.3	57.4
Mean	61.5	59.3	55.4	

This result suggests that for organic vegetable soybean production, cultivar Cha-mame has great potential for growing in Southeast Asia. Since this is a cultivar from Japan, there is high opportunity for Southeast Asian countries to expand production for export market to Japan and other countries.

Incidence of insect pests and diseases

Vegetable soybean is attacked by various insect pests at different plant growth stages. In this trial leaves were slightly defoliated by tomato fruitworm (*H. armigera*), common armyworm (*S. litura*) and beet armyworm (*S. exigua*). Soybean webworm (*Omiodes indicata*) and Taiwan tussock moth (*Porthesia taiwana*) were promising defoliators. Whitefly (*Bemisia tabaci*), thrips (*Megalurothrips usitatus*) and small green leafhopper were the major sucking insects.

Limabean pod borer (*Eteiella zinckenella*) and legume pod borer (LPB), *Maruca vitrata* were the major pests on the pods. Insect pest incidence in general was low and there was no variation among cultivars in terms of insect damage. The integrated pest management consisting of sex pheromones and sticky paper traps, bio-pesticides such as *Bacillus thuringiensis* (Bt), neem and *nucleopolyhedrovirus* (NPV) was effective in managing insect pests to minimum level.

The major diseases observed were root rot (*Rhizoctonia solani*) and anthracnose (*Colletotrichum truncatum*). Other diseases were downey mildew (*Peronospora manshurica*), rust (*Phakopsora pachyrhizi*), purple blotch (*Cercospora kikuchi*) and bacterial pustule (*Xanthomonas axoropodis* pv. Glycine). Disease infection level and occurrence were low in this trial and no difference among cultivars were observed in terms of disease infection. Bio-agents *Trichoderma harzianum* T2 strain (100 X) and *Bacillus subtilis* strains Y1336 (500X) and WG6-14 (100X) were quite effective in controlling disease infection.

CONCLUSION

This study has shown that growth and yield performance varied among vegetable soybean cultivars when grown under organic management systems. In terms of total pod yield promising cultivars are Cha-mame, TNAV 2 and KS 9 with potential yields of 11-12 t/ha. In terms of graded pod yield the three cultivars maintained higher yield (above 6.0 t/ha) compared to KS 6. Both Cha-mame and KS 6 have higher percent graded pod than KS 9 and TNAV 2. Over three growing seasons average yield is greater in spring planting than autumn planting for all cultivars. The incidence of insect pests and diseases was not serious in reducing yield levels in all cultivars. Integrated/organic pest management was effective in bringing down insect population and disease infection. Based on the results of the study, cultivars Cha-mame and TNAV 2 have great potential for organic vegetable soybean production in Southeast Asia for export market. Cha-mame matures early and has ideal qualities suitable for organic export market.

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