Journal of Developments in Sustainable Agriculture 12: 45–51 (2017)

Economic Feasibility of Coconut Coir-Based Hydroponics as an Alternative System for Crop Management in Thailand

Hisashi Urayama[1]*, Hidetoshi Takama[2] and Sachio Maruyama[3]

[1] Overseas Agricultural Development Association, 8–10–32 Akasaka, Minato-ku, Tokyo 107–0052, Japan
[2] former Japan International Cooperation Agency, Tsukuba International Center, 3–6 Koyadai, Tsukuba, Ibaraki 305–0074, Japan
[3] Faculty of Life and Environmental Sciences, University of Tsukuba, 1–1–1 Tennoudai, Tsukuba, Ibaraki 305–8572, Japan.

Coconut coir is an effective growth medium that has been used in hydroponic cultivation of lettuce in Thailand; this material is inexpensive and readily available in tropical regions. Here, we evaluated the financial feasibility of an energy-saving hydroponic system using coconut coir as the growth medium in northeastern Thailand. We first compared coconut coir hydroponic cultivation with the conventional open field cultivation to assess the productivity and marketability of cucumbers in the rainy and dry seasons: in the hydroponic system, profit in the rainy season 57% higher and in the dry season, 95% higher. Next, we assessed a simulation of a new cropping pattern based on the hydroponic system. The assessment included a new 4-year investment in a conventional crop of rice and cucumber in the rainy season and tomato in the dry season, versus an investment in the coconut coir-based hydroponic system for a 0.32 ha (2 rai) field. Incremental cost–benefit values, comparing existing management practices with the new 4-year term, were calculated at a discount rate of 0.0975, which was the lowest concessional loan rate by the Bank of Agriculture and Agricultural Cooperatives. The cost–benefit ratio was 1.14. These findings show that investment in hydroponic cultivation in northeastern Thailand would be cost effective.

Key words: B/C ratio, coconut coir, cropping system, hydroponic media, NPV

Introduction

Crop production in tropical and subtropical zones can be sustainable if soil fertility can be maintained under continuous farming. The use of hydroponic systems can be beneficial to small-scale farmers by enabling them to take advantage of favorable climate conditions to improve productivity. In tropical and subtropical countries, the majority of farmers operate on a small scale, with less than 1 ha of cultivated land. However, medium-scale farmers with more than 2 ha of cultivated land can establish crop rotation systems with cash crop production.

Lowland paddy rice farms are among the most important agricultural systems in tropical Asian countries. Upland crop farming is not as common as post-paddy rice cropping in most of these countries, where cropping systems should be diversified according to the water supply. In Thailand, paddy rice is generally cultivated during the rainy season (May through November), and upland crops are cultivated in paddies during the dry season (December through June); this practice is typical in tropical Asia. A unique cropping system, called the Chinese system, is used to cultivate *Solanaceae*, *Cucurbitaceae*, and *Brassicaceae* plants in large nurseries on the dry paddy fields in this area (Yamada, 2004).

Salinized soils are common in northeastern Thailand, and crop growth is severely inhibited in these soils. Continuous cropping also stresses the soils and

Received: January 13, 2016, Accepted: April 28, 2016
* Corresponding author: Overseas Agricultural Development Association, 8–10–32 Akasaka, Minato-ku, Tokyo, 107–0052, Japan.
Tel: 03–3478–3510, Fax: 03–3401–6048, E-mail: urayama@oada.or.jp

further limits yield in this area. To address these problems, the government is considering a project to install irrigation systems in this region (Sato, 2008). In this study, we investigated the economic feasibility of improving crop rotation systems by using coconut coir media in energy-efficient hydroponic systems (Urayama *et al*., 2005, 2007).

Materials and Methods

Hydroponic systems (Thippayarugs *et al*., 2002) for fruits and leafy vegetables were used at the Khon Kaen Field Crop Research Center to examine energy and cost savings. Absorbent with the type of fabric (e.g., cotton) sheets were evaluated as an alternative growth medium, and energy-saving hydroponic systems using coconut coir (Urayama *et al*., 2005, 2007) were used for cucumbers.

The cost and profitability of cucumber production in a 0.1 ha field was estimated with data from a report by the Agriculture & Livestock Industries Corporation (2007). We used data on current conditions for crop rotation in northeastern Thailand as published in Sato (2008) and Agriculture & Livestock Industries Corporation (2006). General information on the production cost of rice and vegetables and on the average field size and yield of paddy rice were obtained from Kabaki *et al*. (2001), Agriculture & Livestock Industries Corporation (2006, 2007), Sato (2008), and the Food and Agriculture Organization of the United Nations (2008). The data from these reports were used to generate each estimate.

Farm management practices in the four-year cucumber cultivation study were compared between the open field and hydroponic system during the rainy and dry seasons. Financial analysis was performed using the 'Economy Financial Affairs Analysis Method' (Takama and Tomomatsu, 1999) to examine the economics of the two cropping systems.

Net present values (NPV) and benefit/cost (B/C) ratios were calculated as follows (Upton, 1996):

$$\mathrm{NPV} = \sum \frac{\Delta \mathrm{B}}{(1+r)^n} - \sum \frac{\Delta \mathrm{C}}{(1+r)^n} \geq 0$$

and

$$\mathrm{B/C\ Ratio} = \sum \frac{\Delta \mathrm{B}}{(1+r)^n} / \sum \frac{\Delta \mathrm{C}}{(1+r)^n} \geq 1$$

where ΔB is incremental benefit, ΔC is incremental cost, r is the discount rate, and n is the duration of cropping (number of time periods). A project is feasible if the NPV is positive, and B/C ratios >1 indicate a beneficial or economically feasible result. Cash flow was investigated eight times during the four-year study (in the rainy and dry seasons). A 9.75% discount rate was used with the maximum interest rate from the Bank of Agriculture and Agricultural Cooperatives. Benefits and costs were computed at a half discount rate for every half year with a half-year cash flow.

Results and Discussion

The Agriculture & Livestock Industries Corporation report (2007) indicates that the average cucumber yield for open fields is approximately 2.0 kg/m^2 per year. In contrast, cucumber yield in an energy-saving hydroponic system with coconut coir as the growth media was 8.5 kg/m^2, which is 4.2 times the yield for a 2.5-month farming season.

Monthly average shipment prices for the open-field scenario were 3.9 baht/kg (approximately 11.7 yen/kg; 1 baht = 3 yen) (Agriculture & Livestock Industries Corporation, 2007). Shipping costs depend on supply and demand during each season. The average monthly wholesale price in Bangkok for cucumbers from 2006 to 2011 was 16.55 baht during the rainy season (August to November) and 18.11 baht during the dry season (February to May). The total seasonal average price from January 2006 to April 2011 (64 months) was 17.37 baht. The rainy and dry season mean prices were 3.7 baht and 4.1 baht, respectively, which made the average shipment price 3.9 baht for both seasons.

The itemized expenditures for cucumber production are as follows: tillage, 234 baht (702 yen); planting, 129 baht (387 yen); field management, 368 baht (1,104 yen); harvest, 259 baht (777 yen); seeds and seedlings, 393 baht (1,179 yen); fertilizer and other chemicals, 969 baht (2,907 yen); fuel and other consumable materials, 419 baht (1,257 yen). In the hydroponic system, harvest expenses were divided proportionally as yield increased or decreased. Fertilizer expenses in the hydroponic system include the price of culture solution; lettuce cultivation required 1.5-times the water and a growing period 4-times that for cucumber (Thippayarugs *et al*., 2002). Expenses for fuel, chemicals, and labor in the hydroponic system were estimated as half those required for open-field cultivation.

Coconut coir is readily available and inexpensive (Thippayarugs *et al*., 2002; the price of coconut coir is approximately 1 rupee (~1 yen) in Sri Lanka and 1 peso (1–2 yen) in the Philippines. Based on this price,

Table 1. Depreciation expense of energy-saving hydroponics systems (materials only, except consumables and labor cost) in Thailand.

Materials	In Japan		In Thailand	
	Price/unit (yen)	Cost (yen)	Price/unit (baht†)	Cost (baht)
Culture bed	3300/ 1.5 m×0.6 m	1,114,000	225/ 1.2 m×0.6 m	94,875
Floating bulb	2,000	44,000	90	1,980
Absorbing sheet	600/ 1 m×1.2 m	304,000	200/ 1 m×2.0 m	15,484
Root barrier sheet	180/ 1 m×1.2 m	0	30/ 1 m×1.2 m	0
Tank	50,000	1,100,000	550	12,100
Others (piping stems etc.)		500,000		50,000
Total		3,062,000		139,439

† 1baht=3 yen.

the total expense for media for a 1,000 m^2 field (one bed) would be approximately 928 baht (2,784 yen) for 128 kg (23 m×0.6 m), and this could be used for 1 to 2 years. The initial investment required for a hydroponic system with 22 beds for 1,000 m^2 (1 bed=23 m ×0.6 m) is 281,540 baht (844,620 yen) according to Thippayarugs *et al*. (2002); absorbent sheeting accounts for 36% of all expenditures (101,333 baht, 304,000 yen) because of the high costs of importing the sheets from Japan.

Because of this high cost, procurement of absorbent sheeting from Thailand was evaluated, which reduced the cost to 15,484 baht (46,452 yen), equivalent to only 5% of the total expense. After this adjustment, the initial cost of the hydroponic system was estimated as 139,439 baht (104,580 yen) (Table 1), and the total expense for this system was 34,860 baht (189,618 yen) over the four-year period, using a fixed amount with estimated depreciation. Depreciation expenses were then estimated as 17,430 baht (53,290 yen) for a single hydroponic crop of cucumber in the rainy and dry seasons for one year, and total expenditures were 23,914 baht (71,742 yen) (Table 2).

Net rainy season profits for cucumber grown in open fields, assuming a yield of 2.0 kg/m^2 (Agriculture & Livestock Industries Corporation, 2007), were estimated as 4,737 baht (14,211 yen). Net rainy season profit for the hydroponic system, with a yield of 8.5 kg/m^2, was 7,447 baht (22,341 yen), approximately 1.6 times the net income from the open-field scenario (Table 2).

During the dry season, the net income for the hydroponic system was 10,838 baht (32,514 yen), approximately double the income for the open field scenario (Table 2). However, hydroponic systems could be even more profitable, given supermarket values of 14 baht (42 yen) (Japan International Cooperation Agency, 2006), the durability of these energy-saving systems, and the potential to grow high-value crops such as melons and tomatoes.

The profit margins for energy-saving hydroponic systems are higher than those for open-field cropping, especially when materials are domestically procured. Hydroponic systems also enable fruits and vegetables to be grown without compromising the soil health and timing of planting. However, fluctuations in market prices can reduce the estimated end profits. Because farmers do not commonly use hydroponic systems, it is probable that greater income would not be expected until low-cost absorbent sheeting is procured. Most farmlands in the study area are approximately 2 rai (1 rai=0.16 ha). On most farm fields of approximately 2–3 rai (0.32–0.48 ha), fruits vegetables are cultivated and managed by families (Agriculture & Livestock Industries Corporation, 2006). Crop rotations that alternate between rice and vegetables are generally used in the lowlands. In lowland rice-growing areas, most private holdings are divided into 1 rai for paddy fields and 1 rai for vegetables to maintain or improve soil health. Lowland rice planting begins during the rainy

Table 2. Expense of cucumber production in unit area (10 a) compared between field and energy-saving hydroponics in different seasons in Thailand (unit: baht).

Cropping \ Expenditure	Tillage	Transplaning	Field management	Harvest	Seeds and seedlings	Fertilizers and chemicals
Cucumber (wet)	234	129	368	259	393	969
Cucumber (dry)	234	129	368	259	393	969
Cucumber (energy-saving hydroponics) (wet)	234	129	368	1,082	786	2,538
Cucumber (energy-saving hydroponics) (dry)	234	129	368	1,082	786	2,538

Cropping \ Expenditure	Fuel and consumables	Culture medium	Depreciation expense	Expenditure (total)
Cucumber (wet)	419	0	0	2,770
Cucumber (dry)	419	0	0	2,770
Cucumber (energy-saving hydroponics) (wet)	419	928	17,430	23,914
Cucumber (energy-saving hydroponics) (dry)	419	928	17,430	23,914

Cropping \ Income	Yield (kg 10 a^{-1})	Initial price (baht† kg^{-1})	Gross income	Net income
Cucumber (wet)	2,029	3.7	7,507	4,737
Cucumber (dry)	2,029	4.1	8,319	5,549
Cucumber (energy-saving hydroponics) (wet)	8,476	3.7	31,361	7,447
Cucumber (energy-saving hydroponics) (dry)	8,476	4.1	34,752	10,838

season, and vegetables are used as feed for piglets and as cash crops. Maize and beans are also used in rotation with rice. Livestock farmers also plant lowland rice as a cash crop, and cassava and maize are included in the rotation.

Farmers who practice lowland crop rotation have an annual income of approximately 15,000 baht (45,000 yen). In contrast, the average annual income of a farmer in Thailand is approximately 72,000 baht (216,000 yen) (Sato, 2008).

The profit from an energy-saving hydroponic system that produces two cucumber harvests is clearly greater than that obtained using the open-field method, which produces just one cucumber crop per year. However, hydroponic systems limit the scale or size of the field to 0.6 rai (~0.1 ha) because of the amount of media and

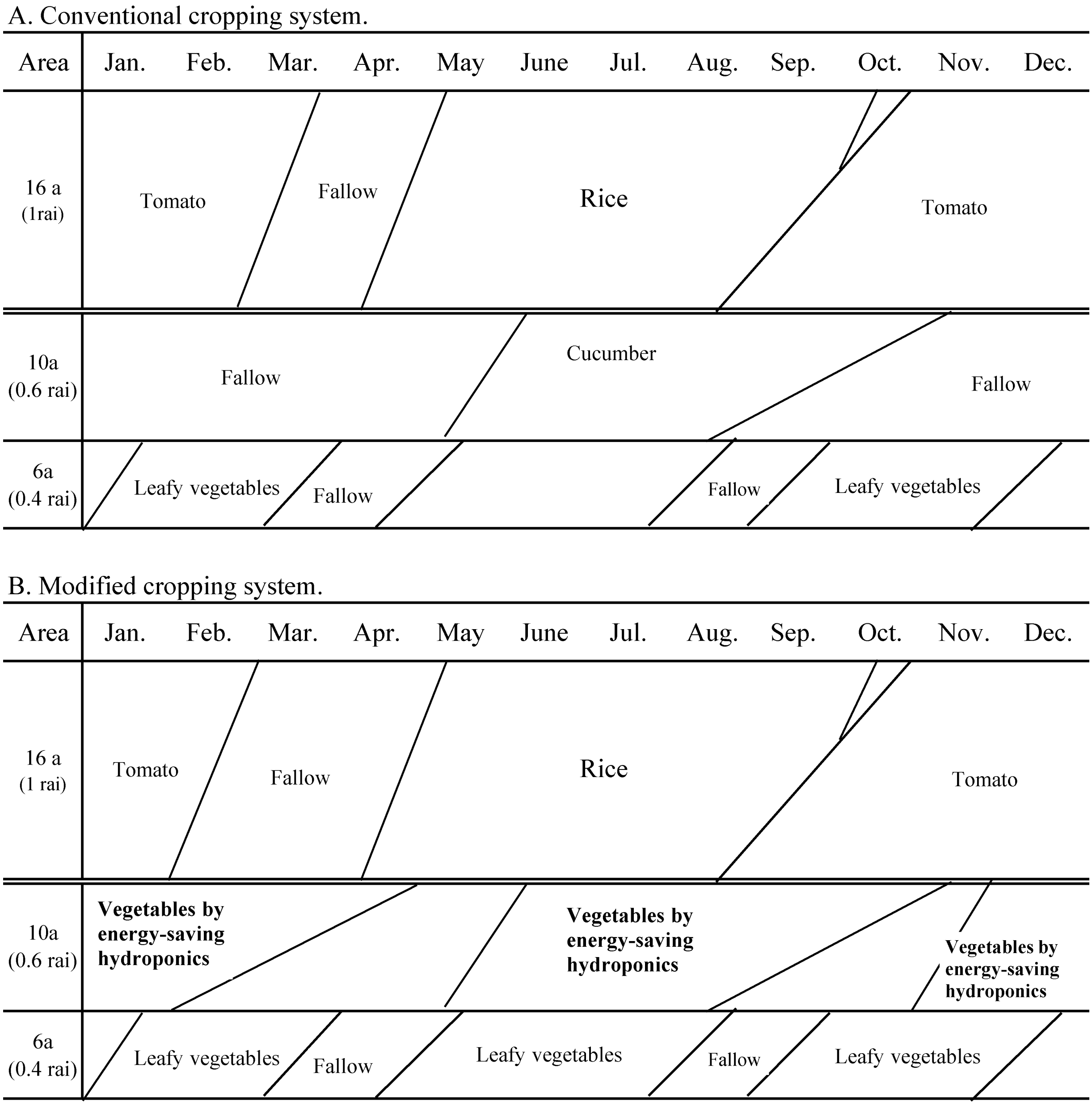

Fig. 1. A pattern of conventional crop rotation system (A) and modified (new) crop rotation system (B) for the small-scale farmers in Thailand.

labor needed. Therefore, a field size of 2 rai would be ideal for farm management when incorporating a hydroponic system; one rai could be allocated to lowland rice during the rainy season, and one rai should be allocated to vegetable production (Fig. 1). A 0.6 rai field can be used for one harvest, and the remaining 0.4 rai (~600 m^2) can be used for vegetables.

The net income for lowland rice farming (one harvest) is estimated as 1,261 baht (2,364 yen), with an average yield of 2,350 kg (Kabaki *et al.*, 2001) and a market price of approximately 5.2 baht/kg (15.6 yen/kg). We estimated the cost of labor and materials (e.g., fertilizer) as 694 baht/rai (2,082 yen/rai) for a family farm business in Thailand (Japan International Cooperation Agency, 1998). From these values, the net benefit of conventional cropping during the rainy season was estimated as 5,998 baht/260 m^2 (17,994 yen/260 m^2), adding a net profit of 4,737 baht/0.1 ha (14,211 yen/0.1 ha) to conventional open-field cucumber production (rice + cucumber). If tomato produc-

Table 3. Cash flow between conventional cropping and modified cropping patterns in season wise.

(unit: baht)

	Conventional cropping		Modified cropping								Total NPV
	—		year 1		year 2		year 3		year 4		
	rainy	dry	rainy	dry	rainy	dry	rainy	dry	rainy	dry	
Gross value of production	9,462	13,838	33,316	48,590	33,316	48,590	33,316	48,590	33,316	48,590	
Incremental value of production	—	—	23,854	34,752	23,854	34,752	23,854	34,752	23,854	34,752	
Expenses	3,464	2,200	146,601	8,668	7,162	8,668	7,162	8,668	7,162	8,668	
Incremental expenses	—	—	143,137	6,468	3,698	6,468	3,698	6,468	3,698	6,468	
Net benefit	5,998	11,638	−113,285	39,922	26,154	39,922	26,154	39,922	26,154	39,922	
Incremental net benefit/cash flow			−119,283	28,284	20,156	28,284	20,156	28,284	20,156	28,284	
$NPV=\frac{\Delta B}{(1+r)^n}-\frac{\Delta C}{(1+r)^n}$			−113,738	25,716	17,474	23,380	15,887	21,257	14,444	19,327	23,748

tion is included after lowland rice farming, gross profits would be approximately 13,838 baht/rai (41,514 yen/rai), with an estimated yield of approximately 4,613 kg/rai (Agriculture & Livestock Industries Corporation, 2007) and market price per kg of 3 baht (~9 yen) (Agriculture & Livestock Industries Corporation, 2006). From these values, the net profit for tomato would be approximately 11,638 baht/rai (34,914 yen/rai) before subtracting material expenses (e.g., fertilizer) for cucumber production (approximately 2,200 baht/rai). Ultimately, the net profit for conventional farming in the rainy and dry seasons was estimated as 17,636 baht (52,908 yen/rai) (Table 3).

When energy-saving hydroponic systems are introduced into farming, the estimated net income increases (Table 2). Our estimated cash flows for conventional and modified (hydroponic) cropping systems reflect four years of depreciation of the energy-saving system (Table 3). Investments in plants and equipment are estimated as 139,439 baht (418,317 yen); the cost of labor are estimated as 8,668 baht during the dry season and 7,162 baht during the rainy season. The incremental values of production and expense, the total net present value, and the benefit/cost ratio (1.14 at a discount rate of 9.75% as the annual interest rate) indicate a good return on investment (Table 3).

Coconut coir growth media can be considered a viable substitute for chemical fertilizers because it accumulates potassium and nitrogen for the life of the media, which is approximately one to two years with continuous farming (Urayama *et al*., 2005). After coconut coir has been used in a hydroponic system, it can be composted or incorporated into the soil (Koyama *et al*., 2009). It can also be used as a growth media to improve hydroponic rice production (Urayama and Maruyama, 2009). Compared to conventional (open field) farming, the net income for a hydroponic system is approximately 57% greater in the rainy season and 95% greater in the dry season (Table 2).

In conclusion, this financial analysis shows that modified cropping systems that use coconut coir as a hydroponic growth media can be profitable and farming can enable repayment of loans accumulated through farming practices

References

Agriculture and Livestock Industries Corporation, 2006. Vegetable Information, Vol.22. (in Japanese)

Agriculture and Livestock Industries Corporation, 2007. Report on Collected Information of Imported Vegetables, 20–36.

Food and Agriculture Organization of the United Nations, 2008. FAOSTAT, http://faostat.org/site/.

Japan International Cooperation Agency (JICA), 1998. Report on Management of Modern Irrigation and Drainage System for Sustainable Agriculture Development in the Kingdom of Thailand. (in Japanese)

Japan International Cooperation Agency (JICA), 2006. Report on Appropriate Techniques of Agricultural Chemicals in Northern Thailand. (in Japanese)

Kabaki, N., Morita, H., Fujimori, S., Arromratama, U., T. Na Nanagara, 2001. Technologies for rainfed rice production in Northeast Thailand. Research Highlights. Crop, Livestock and Environment Division Japan International Research Center for Agricultural Sciences, 9, 17–18. (in Japanese)

Koyama, S., H. Urayama, K.M.P.D. Karunaratne, T. Yamashita, 2009. Effects of Coir Application on Soil Property and Cucumber Production as a Reuse model of Organic Medium Used in Soilless Culture. Trop. Agr. Develop. 53, 7–13.

Sato Kazunori, 2008. Monthly Report on Vegetables -Overseas Information- http://www.vegenet.jp/yasaijoho/kaigai/0809/kaigai.html. (in Japanese)

Takama, H., A. Tomomatsu, 1999. Economic Analysis of Agricultural Development Project –Prospects and Subjects of International Cooperation-, 92–101. (in Japanese)

Thippayarugs, S., K. Suzuki, Y. Katsuta, A. Yoshida, N. Matsumoto, N. Kabaki and C. Wongwiwatchai 2002. Vegetable production using energy-saving hydroponics systems in Khon Kaen. JIRCAS Working Report No. 30, 161–165. (in Japanese with English abstract)

Martin Upton, 1996. The economics of tropical farming systems. CAMBRIDGE UNIVERSITY PRESS, pp. 315–325.

Urayama, H., L. J. Matthews, V. J. Coetzee, T. Yamashita, 2005. Cucumber Cultivation in Energy-Saving Hydroponic System Using Coconut Coir as Growing Media. Japanese Journal of Tropical Agriculture 49, 154–158. (in Japanese with English abstract)

Urayama, H., A. P M. Irungu, P. K. Chege, D. T. Moabi, T. Yamashita, 2007. Effect of Coconut Coir Media on Bitter Gourd (*Momordica charatia* L.) Growth and Yield in an Energy-Saving Hydroponic System. Japanese Journal of Tropical Agriculture 51, 177–182. (in Japanese with English abstract)

Urayama, H., S. Maruyama 2009. Raising of Rice Seedlings for Manual Transplanting by Hydroponics Using Coconut Coir as Culture Media. Trop. Agr. Develop. 53, 97–102.

Yamada Mitate, 2004. Cropping System, New Agriculture Encyclopedia. Yokendo, pp. 995–1003. (in Japanese)