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Energy analysis of green manure managements on organic riceberry rice production

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Abstract. Rice production in Thailand has been an important part of the Thai economy. In this research, was analyzed and compared energy use pattern for organic rice production in different green manure managements. The rice variety used was Riceberry. The study was conducted from July 2017 to January 2018 on the long-term agricultural field trial at Lamphun province, Thailand. Each field was divided into three equal parts (*Crotalaria juncea*, *Sesbania rostrata* and Control treatments). The results showed that the main energy consumption in organic rice production came from fuel (60%) and machinery (30%), moreover green manures treatments increased slightly total energy input but gave large total energy output more than control treatment. The energy use efficiency of sesbania, control and crotalaria were 8.18, 5.59 and 7.28, respectively, while the net energy were 18,864.41, 7,521.57 and 2,547.13 MJ Rai⁻¹ (1 Rai = 0.16 Hectare = 1,600 m²), respectively, as well as the energy productivity were 0.28, 0.18 and 0.25 kg MJ⁻¹, respectively. Therefore, in this study using sesbania as green manure before planting was suitable for organic rice production since the highest values in the energy use efficiency, the net energy and the energy productivity when compared with the other treatments.

1. Introduction

Rice (*Oryza sativa* L.) is the main cereal of the world. Rice is classified as the same species of grass which is the largest size of grass in the world. Rice can be planted easily and resistant to all landscape conditions in the world. The world population consumes rice in both of gain and processed rice products. Rice production in Thailand has been an important part of the Thai economy. For seven months in 2018 (January-July), Thailand was the second largest exporter of rice in the world. Moreover, the total value of Thai rice export was 99.6 billion baht [1]. Many rice varieties have a health promoting properties, especially Riceberry which is a registered rice variety from Thailand. Riceberry is dark purple rice that is cross-breed between Jao Hom Nin and Khao Dawk Mali 105. The dark-purple pigment in Riceberry is anthocyanin that can be dissolved well and classified as a group of flavonoids or and the effective antioxidants. Riceberry has oval and long shape as well as unique aroma. The rice can be grown throughout the year which is harvested about 130 days after planting [2].

In developing countries, the demand for energy has increased rapidly, which is the result of economic growth. Rice farming requires both direct and indirect energy. A number of studies on the energy input in rice farming focused on inorganic rice production [3-9]. However, few studies have been published on the energy analysis of organic rice production in Thailand. This study aims to fill



this gap by comparisons of energy and yield of green manure managements on organic Riceberry rice production.

2. Material and Methods

2.1. Preparation of experimental plots.

The study was conducted from July 2017 to January 2018 on the long-term agricultural field trial at Banthi district, Lamphun province, Thailand. Each field was divided into three equal parts (Crotalaria juncea, Sesbania rostrata and Control treatments). The size of each experimental plot was 25 m² (5 m x 5 m) with 3 plots in each treatment and separated each other by bunds. The rice variety used was Riceberry. A subsubsection.

2.2. Preparation of green manure

Three treatments were used (three replicates per treatment) (Figure. 1): (1) C, control plot (no green manure planting); (2) Cj, plot planted Crotalaria juncea green manure (Figure. 2); (3) Sr, plot planted Sesbania rostrata green manure (Figure. 3). Five kg Rai-1 of each green manure was transplanted by seedling in each plot then plowed the green manures 60 days after seedling.



Figure 1. The experimental plots.



Figure 2. *Crotalaria juncea* plots.



Figure 3. *Sesbania rostrata* plots.

2.3. Crop management

The green manure was plowed and incorporated into the soil then left for 3 days. The field was flooded and harrowed to break the soil clods into smaller mass. The green manure residue was later left for 10 days for fermentation. Water was released from the field to allow for weed seeds to germinate. The field was flooded and leveled before rice planting. Rice seedling at 25 days of age was

transplanted on each experimental plot on a 25 cm x 25 cm spacing. The field was continuously flooded (3-5 cm) until 10 days before harvesting then the water was released from plots.

2.4. Energy analysis

The energetic efficiency of the agricultural system has been appraised by the energy ratio between output and input. The energy ratio has been calculated using human labor, machinery, diesel fuel, green manure management, seed amounts and output yield values of rice crop. Table 1 shows energy equivalents used to appraise the input and output energy. Table 2 shows the demonstrated quantity of inputs in two green manure managements. The tractor and power tiller were the sources of mechanical energy that have been used on the farms and this included energy for manufacturing, repairs and maintenance. The basis of total fuel consumption (L Rai⁻¹) in different green manure managements has been calculated from diesel energy. The following equations (1)-(4) were used for computing the total energy equivalents of the inputs and output (Table 1), the energy use efficiency (energy ratio), net energy, energy productivity and specific energy [10].

$$\text{Energy use efficiency (EUE)} = \text{Energy Output (MJ Rai}^{-1}\text{)} / \text{Energy Input (MJ Rai}^{-1}\text{)} \quad (1)$$

$$\text{Net energy (NE)} = \text{Energy Output (MJ Rai}^{-1}\text{)} - \text{Energy Input (MJ Rai}^{-1}\text{)} \quad (2)$$

$$\text{Energy productivity (EP)} = \text{Grain output (kg Rai}^{-1}\text{)} / \text{Energy Input (MJ Rai}^{-1}\text{)} \quad (3)$$

$$\text{Specific energy (SE)} = \text{Energy Input (MJ Rai}^{-1}\text{)} / \text{Grain output (kg Rai}^{-1}\text{)} \quad (4)$$

Table 1. Energy equivalent of inputs and outputs in organic rice production.

Particulars	Unit	Energy equivalent (MJ unit ⁻¹)	References
<i>Inputs</i>			
Human	h	1.96	[8, 11]
Fuel (Diesel)	L	43.30	[8, 12]
<i>Machinery</i>			
- Tractor	h	62.70	[11]
- Weed cutter	rai	0.82	[13, 15]
- Pumping	h	6.80	[13, 15]
- Power sprayer	rai	0.86	[13, 15]
- Harvesting machine	rai	709.96	[8]
- Bio-ferment fertilizer	L	0.408	[12, 14]
<i>Seed</i>			
- Green manure seed	kg	7.97	[15]
- Rice seed	kg	14.57	[12]
<i>Outputs</i>			
Paddy rice	kg	14.57	[12]
Straw	kg	12.50	[11]

3. Results and discussion

3.1. Energy input and output

3.1.1. Energy input. The results showed that the total amount of energy for rice production in using sesbania (2,626.55 MJ Rai⁻¹) was higher than crotalaria (2,600.16 MJ Rai⁻¹) and control (2,473.53 MJ Rai⁻¹) because of the value high Energy consumption in fuel components (61.00%). In addition to other management, the maximum energy consumption in rice production was fuel energy, which was 60.78% (crotalaria) and 61.27% (control) of total energy use. The higher fuel consumption of the *Sesbania rostrata* can be used for higher mechanical handling (865.22 MJ Rai⁻¹) in the management of the crotalaria plot (864.40 MJ Rai⁻¹). Since the stems of the 60 days sesbania tree were heavier than the Crotalaria tree, the stem size of sesbania trees must be reduced before preparing the soil. Similarly, the using of sesbania in organic rice production showed that the input of the machine was significantly greater than the crotalaria and control (Table 2). The energy input in the form of human energy was the highest in the management of sesbania trees due to the reduction of stems of sesbania trees before plowing. The using of energy in seeds has a higher level of green manure management than the control plots because the control plots were not produce green manure. It was important to focus on fuel and machinery rather than other factors to reduce energy consumption in organic rice production.

Table 2. Energy consumption of inputs and outputs of organic rice production for different green manure managements.

Inputs and outputs	Total energy consumption (MJ Rai ⁻¹)		
	Control	crotalaria	sesbania
<i>Inputs</i>			
Human	24.99	26.13	30.05
Machinery	843.71	864.40	865.22
Fuel	1515.50	1580.45	1602.10
Seed	72.85	112.70	112.70
Fertilizer	16.48	16.48	16.48
Total energy input	2473.53	2600.16	2626.55
<i>Outputs</i>			
Paddy rice	6520.37	9445.44	10562.96
Straw	7296.00	9472.00	10928.00
Total energy output	13816.37	18917.44	21490.96

3.1.2. Energy output. Table 2 shows the energy consumption of inputs and outputs of organic rice production in the management of different green manure which was calculated from paddy and rice straw production. Therefore, high energy output was found in high yield management. The average energy in the form of paddy and rice straw was 10,657.21, 10,928 MJ Rai⁻¹ in the management of Sr, 9,529.00, 9472.00 MJ Rai⁻¹ in Cj and 6,578.54, 7296.00 MJ.Rai⁻¹ in control, respectively. The energy output in Cj was persistently lower than that in Sr, which was participatory with low yield due to Sr released more nutrient contents into soil [16].

3.2. Energy Analysis of organic rice production

Energy efficiency (EUE), net energy (NE), energy output (EP) and specific energy (SE), in the management of C, Cj and Sr were scheduled in Table 3. The EUE is one of the best indexes for input-

output energy analysis in crop production to indicate the efficient use of energy [17]. In the present study, EUE was between 5.59 in C to 8.18 in Sr, indicating that Sr was a plant management that saves energy.

The NE was higher in Sr than in Cj and C. The mean NE was 18,864.41, 16,317.28 and 11,342.84 MJ Rai⁻¹ in Sr, Cj and C, respectively. The average values of EUE and NE in Sr clearly increased 12.46%, 15.61% and 46.49%, 66.31% as compared to Cj and C, respectively according to the order EUE, NE. The higher EUE and NE values in the green manure than in the control were mainly ascribed to the increase in input power (such as energy obtained from fuel, machinery and human labor), but were caused by a significant increase in energy output. The average value of EP was 0.18, 0.25 and 0.28 kg MJ⁻¹ in C, Cj and Sr, respectively. The results showed that 181, 249 and 276 kilograms per unit of input energy (GJ) in C, Cj and Sr, respectively, while SE indicated the opposite trend. SE refers to the energy used to produce one unit of cereal [11]. A lower SE was observed in Sr (3.62 MJ kg⁻¹) than in Cj (4.01 MJ kg⁻¹) and in C (5.53 MJ kg⁻¹). The higher energy consumption in Sr resulted in higher EP but lower SE. The SE values obtained from this study were lower than the previous values 4.37 MJ kg⁻¹ [18] 6.83 MJ kg⁻¹ [4], 5.65 MJ kg⁻¹ [6], 6.77 MJ kg⁻¹ [8], but SE values were higher than previously reported values, 3.23 MJ kg⁻¹ [5], 3.10 MJ kg⁻¹ [19] (Table 4).

Table 3. Energy analysis of organic rice production in different green manure managements.

Items	Unit	Green manure managements		
		Control	crotalaria	sesbania
Energy use efficiency	-	5.59	7.28	8.18
Net energy	MJ Rai ⁻¹	11342.84	16317.28	18864.41
Energy productivity	kg MJ ⁻¹	0.18	0.25	0.28
Specific energy	MJ kg ⁻¹	5.53	4.01	3.62

Table 4. Literature values for rice cultivation specific energy.

Country	Specific energy (MJ kg ⁻¹)	Source
China	6.83	[4]
Philippines	3.23	[5]
Japan	5.65	[6]
Thailand	6.77	[8]
Philippines	4.37	[18]
Italy	3.10	[19]

4. Conclusion

This research indicates the evaluation of energy analysis of organic rice production in different green-manure managements. The results suggested that the main energy consumption in organic rice production came from fuel and machinery (about 60% and 30%, respectively). Green manures increased slightly total energy input but gave large total energy output more than control treatment. Energy use efficiency, Net energy and Energy productivity was highest in sesbania plot 8.18, 18,864.41 MJ Rai⁻¹ and 0.28 kg MJ⁻¹, respectively, on the other hand the specific energy was highest

in Control plot 5.53 MJ kg⁻¹. Therefore, in this study using sesbania as green manure before planting was suitable for organic rice production.

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