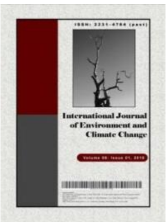

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Comparative Study of Energy Utilization and Green House Gas Emission by Hybrid Rice Grown under Two Different Cultivation Systems in Red Lateritic Zone of West Bengal

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Authors' contributions

This work was carried out in collaboration among all authors. Author AG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SD and MHR managed the analyses of the study. Author SKM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out at Agriculture Farm, Palli Siksha Bhavana, Visva-Bharati, Sriniketan, West Bengal, India during kharif season of 2015 to compare rice cultivation in conventional transplanting (CT) and system of rice intensification (SRI) in terms of energy use, energy input output relationship and green house gas emission. Results showed that regardless of cultivars, conventional transplanting consumed 62.39% higher energy over SRI. Maximum energy input was associated with non renewable and indirect sources. Higher dose of nitrogenous fertilizer

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had contributed to 32.35% and 26.26% to the total input energy in CT and SRI respectively. Energy use efficiency (13.22), energy productivity (6.94 kg MJ^{-1}), energy profitability (12.22) and energy intensity (4.60 MJ Rs^{-1}) of hybrid rice varieties were noted higher in SRI. Maximum green house gas emission from rice field was also attributed to fertilizer nitrogen followed by diesel in both the system. Total green house gas emission in CT was estimated to 834.85 (kg CO_2ha^{-1}) i.e. 1.8 times of SRI. Engirdling different energy indices, total input energy and green house gas emission, the system of rice intensification was emerged as the most energy efficient and sustainable rice production system in resource stricken areas (Red Lateritic Zone).

Keywords: Hybrid rice; conventional transplanting; system of rice intensification; energy utilization; Green House Gas (GHG) emission.

1. INTRODUCTION

Agriculture is one of the most important key sectors and influenced by direct and indirect energy use [1,2]. Among different agricultural crops, rice is world's single most important food crop, being the primary food source for more than one third of global population. Mishra and Salokhe (2010) [3] estimated that the growing population will require 40% more rice production by the year 2050. Increased population coupled with low arable land and higher standers of living, driven farmers towards high energy intensive cultivation practices such as high amount of chemical fertilizer, plant protection chemicals, diesel, electricity and irrigation. Although energy use depends largely on resource availability and the capacity of farmers to afford, rice itself a high energy intensive crop and contributor to greenhouse gas [4]. Along with other inputs conventional rice cultivation demands huge water, that is one of the most important energy intensive inputs for agricultural production [5]. Besides requirement of high water, land preparation also contributes to high energy inputs. Efficient energy use not only reduces environmental degradation and cost of production [6] but also helps in increasing production, productivity, profitability and sustainability [7].Estimation of energy input output relationship i.e. energy budgeting is crucial for development of energy efficient and sustainable agricultural production system in present day agriculture [8]. Energy efficient agricultural system can be achieved by reduced special and temporal use of current resources coupled with broad term tightly defined technologies [9].among the different systems of rice production, system of rice intensification (SRI) can be grouped as one of the most energy efficient rice cultivation practice. So, this study was taken to compare rice cultivation under two different systems of rice production in terms of energy utilization and green house gas emission in red and lateritic zone of West Bengal.

2. MATERIALS AND METHODS

The field experiment was conducted at Agriculture Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal during *kharif* season of 2015. The experiment consisted of ten treatments combination was laid out in split plot design with three replications including two systems of rice cultivation viz. conventional transplanting (CT) and system of rice intensification (SRI) as main plot treatments and five rice hybrids – four Bayer’s hybrids namely 6129 Gold, Tej Gold, 6444 Gold, Prima Gold and one hybrid check (PHB 71) in sub plot. Initial land preparation was done by ploughing with tractor and thereafter, beds were prepared for transplanting in SRI. In case of SRI, the weed management had been carried out with cono-weeder.

2.1 Energy Budgeting

The input energy (Table 3) was calculated by multiplying the equivalent energy of different inputs with their respective quantity per unit (Table 1). Amount of main product (grain) and byproduct (straw) was multiplied with their corresponding energy equivalents (Table 1) to calculate total energy output (Table 4).

Sources of energy were categorized in terms of direct and indirect energy input [10,11,12] or renewable and non-renewable energy input. Human labour, diesel, electricity and irrigation water were grouped as direct energy whereas seed, plant protection chemical, fertilizer, manures and machinery capitalized as indirect energy sources. Renewable energy sources include human labour, seed, irrigation water and manure; while non-renewable sources are diesel,

Table 1. Energy equivalents of different inputs involved in rice production

Particulars		Unit	Equivalent energy (MJ)	Reference
Inputs				
Human labour	Adult man	Hour(h)	1.96	[13]
Fuel (Diesel)		Litre	56.31	[14]
Farm machinery		hour	62.7	[15]
Fertilizers	Nitrogen	kg	60.6	[15]
	Phosphorus	kg	11.1	[15],[16],[10]
	Potassium	kg	6.7	[15]
	Zinc	kg	8.40	[13]
	Sulphur	kg	1.12	[17]
FYM		ton	0.30	[13]
Plant protection chemicals	Fungicides and insecticides	kg	120	[15]
Irrigation water		M^3	1.02	[18]
Electricity		kWh	3.60	[18]
Seed		kg	3.60	[19]
Output				
Rice grain		kg	15.70	[20]
Rice straw		kg	12.50	

Table 2. Carbon dioxide equivalent values of different inputs used in rice cultivation

Inputs	Unit	GHG coefficient (kg CO_{2equ}/unit)	References
Machinery	Hour	0.071	[21]
Diesel	L	2.76	[22]
Nitrogen	Kg	3.27	[23]
Phosphorus	Kg	1.34	[23]
Potassium	Kg	0.642	[23]
Zinc	Kg	4.18	[24]
Sulphur	Kg	0.06	[25]
Plant protection chemicals	Kg	5.1	[26], [27]

electricity, plant protection chemical, fertilizer and machinery.

Net Energy Gain (MJ ha^{-1}) = Energy output – Energy input

$$\text{Energy Use Efficiency} = \frac{\text{Energy output (MJ ha−1)}}{\text{Energy input (MJ ha−1)}}$$

$$\text{Specific Energy (SE)} = \frac{\text{Energy input (MJ ha−1)}}{\text{Crop economic yield (Kg ha−1)}}$$

$$\text{Energy Productivity (EP)} = \frac{\text{Crop economic yield (Kg ha−1)}}{\text{Energy input (MJ ha−1)}}$$

$$\text{Energy Intensity (EI)} = \frac{\text{Energy input (MJ ha−1)}}{\text{Cost of production (Rs ha−1)}}$$

$$\text{Energy Profitability} = \frac{\text{Net energy (MJ ha−1)}}{\text{Energy input (MJ ha−1)}}$$

2.2 Estimation of Green House Gas Emission

Green house gas emission was calculated by multiplying inputs with their corresponding CO_2 emission equivalent (Table 2).

3. RESULTS AND DISCUSSION

The amount of total input energy was more under conventional transplanting method (22481.2 MJ) as compared to SRI system (13844.02 MJ ha^{-1}) (Table 3). Result revealed that out of total input energy, the contribution of nitrogen fertilizer was maximum in both CT (32.35%) and SRI (26.26%). The sharing of irrigation water (19.06%) was also the higher followed by diesel fuel (13.78%) and electricity (12.10%) in CT,

Table 3. Energy consumption in Conventional Transplanting (CT) and System of Rice Intensification (SRI)

Input	Quantity per unit area (ha)		Energy equivalent	Total energy equivalent (MJ ha^{-1})		Percentage of total energy input	
	CT	SRI		CT	SRI	CT	SRI
				(energy)	(energy)		
Human labour (h)	784	880	1.96	1536.64	1724.80	6.84	12.46
Machinery (h)	11	11	62.7	689.70	689.70	3.07	4.98
Diesel fuel (L)	55	55	56.31	3097.05	3097.05	13.78	22.37
Chemical Fertilizer (kg)							
(a) Nitrogen	120	60	60.6	7272.00	3636.00	32.35	26.26
(b) Phosphate	60	30	11.1	666.00	333.00	2.96	2.41
(c) Potassium	60	30	6.7	402.00	201.00	1.79	1.45
(d) Zinc	25	0	8.4	210.00	0.00	0.93	0.00
(e) Sulphur	45	0	1.12	50.40	0.00	0.22	0.00
Farmyard manure (kg)	0	10	0.3	0.00	3.00	0.00	0.02
Chemicals (kg)	12.5	9.5	120	1500.00	1140.00	6.67	8.23
Water for irrigation (m^3)	4200	1800	1.02	4284.00	1836.00	19.06	13.26
Electricity (kWh)	755.40	323.74	3.6	2719.42	1165.47	12.10	8.42
Seeds (kg)	15	5	3.6	54.00	18.00	0.24	0.13
Total Input				22481.21	13844.02	100.00	100.00

Table 4. Total energy equivalent of outputs in two systems of rice production

Variety	CT	SRI	Energy equivalent	Total energy equivalent (MJ)	
				CT	SRI
Grain (kg ha^{-1})					
H1	4814	5586	15.7	75580	87700
H2	5547	4622		87088	72565
H3	5995	6838		94122	107357
H4	6166	6901		96806	108346
H5	6565	6668		103071	104688
Straw(kg ha^{-1})					
H1	4768	4277	12.5	59600	53463
H2	6760	5557		84500	69463
H3	8062	7745		100775	96813
H4	10139	9365		126738	117063
H5	9148	7817		114350	97713

*** H1: 6129 Gold, H2: Tej Gold, H3: 6444 Gold, H4: Prima Gold, H5: PHB 71*

whereas the trend of contribution was different in SRI i.e. the diesel fuel (22.37%) being thesecond highest consumer followed by irrigation water (13.26%) and human labour (12.46%). Erdal et al. (2007) [28] and Mobtaker et al. (2010) [29] also reported that diesel fuel and fertilizers were the most intensive inputs in terms of energy consumption. Total energy consumption was 62.39% higher in CT as compare to SRI due to its higher seed rate, irrigation, chemical fertilizers and plant protection chemical demands (Table 3). Although hybrids recorded higher straw yield under CT but their performance was better in SRI in terms of Grain yield. Production of higher straw yield in CT leaded to 17.03% higher output energy than SRI (Table 4). Jayadeva et al. (2010) [30] and Babu et al. (2014) [31] also recorded higher grain yield and lower energy requirement of SRI but in contrast with the present study the straw yield was also noted higher in SRI.

Except specific energy all other energy indices viz. net energy, energy use efficiency, energy productivity, energy intensity and energy profitability was higher in SRI (Table 5). SRI had gained 2% more net energy compared to CT due to its lesser energy input. Energy use efficiency ranged from 6.0 to 9.9 in five hybrids under CT with maximum for hybrid Prima Gold (9.9) whereas the range varies from 10.2 to 16.3 in SRI with utmost value in same variety (Table 5). Energy intensity was 4.60 MJ Rs^{-1} in SRI which was 5.5% higher than CT. SRI also recorded 70.94% and 65.36% more energy productivity and energy profitability respectively over CT. The variety Prima Gold showed superiority in terms of net energy, energy use efficiency, energy intensity and energy profitability in both the systems of rice cultivation. Khan et al. (2009) [32] concluded that environmental impact of crop production associated with Specific energy and energy input output ration.

Experiment disclosed that the sharing of direct energy source were 51.6% and 56.8% in CT and SRI respectively which was higher than indirect sources (Table 6). Among two systems of rice cultivation SRI consumed more direct energy than CT whereas the pattern was just reverse in case of indirect energy, i.e. CT consumed 11% more indirect energy over SRI. Total energy consumption was further divided into renewable and non renewable energy. Overall non renewable energy consumption was much higher in both the systems of rice cultivation. Percent share of renewable energy was slight lesser for SRI (25.9%) as compared to CT (26.1%). This was attributed to higher seed rate and irrigation water requirement in CT.

The study pointed out that highest green house gas emission in rice cultivation was associated with nitrogen fertilization followed by diesel fuel (Table 7). Nitrogenous fertilizer alone contributed 47% (Fig. 1) and 43% (Fig. 2) to the green house gas emission in CT and SRI system of rice cultivation respectively. Due less inputs requirement in SRI, sharing of nitrogen and diesel in emission of green house gas was more

Table 5. Energy input – output relationship and energy indices for Conventional Transplanting (CT) and System of Rice Intensification (SRI)

		Net energy (MJ ha^{-1})	**Energy use efficiency**	**Specific energy (MJ kg^{-1})**	**Energy productivity (Kg MJ^{-1})**	**Energy intensity (MJ Rs^{-1})**	**Energy profitability**
CT	H1	112698.6	6.0	0.30	3.4	3.1	5.0
	H2	149106.7	7.6	0.26	3.9	4.0	6.6
	H3	172415.3	8.7	0.24	4.2	4.5	7.7
	H4	201062.5	9.9	0.23	4.3	5.2	8.9
	H5	194939.3	9.7	0.22	4.6	5.1	8.7
Mean		166044.47	8.39	0.25	4.06	4.36	7.39
SRI	H1	127319	10.2	0.16	6.3	3.6	9.2
	H2	128184	10.3	0.19	5.2	3.6	9.3
	H3	190325	14.7	0.13	7.8	5.1	13.7
	H4	211564	16.3	0.13	7.8	5.7	15.3
	H5	188556	14.6	0.13	7.6	5.1	13.6
Mean		169189.58	13.22	0.15	6.94	4.60	12.22

*** H1: 6129 Gold, H2: Tej Gold, H3: 6444 Gold, H4: Prima Gold, H5: PHB 71*

Table 6. Types of energy and percent sharing in Conventional Transplanting (CT) and System of Rice Intensification (SRI)

Types of energy	**CT**		**SRI**	
	Total energy equivalent (MJ ha^{-1})	**Percentage of total energy input**	**Total energy equivalent (MJ ha^{-1})**	**Percentage of total energy input**
Drect Energy	11637.1	51.8	7823.3	56.8
Idirect energy	10844.1	48.2	6020.7	43.5
Renewable Energy	5874.6	26.1	3581.8	25.9
Non renewable Energy	16606.6	73.9	10262.2	74.1

Table 7. Amount of greenhouse gas emission from inputs of Conventional Transplanting (CT) and System of Rice Intensification (SRI)

Inputs	**GHG coefficient (kg CO_2equ/unit)**	
	CT	**SRI**
Machinery (h)	0.78	0.78
Diesel fuel (L)	151.80	151.80
Nitrogen(kg)	392.40	196.20
Phosphate(kg)	80.40	40.20
Potassium(kg)	38.52	19.26
Zinc(kg)	104.50	0.00
Sulphur(kg)	2.70	0.00
Chemicals (kg)	63.75	48.45
Total emission(kg CO_2 ha^{-1})	834.85	456.69
Average yield of five hybrids (kg ha^{-1})	13592.80	13075.20
Emission (kg CO_2e kg^{-1} rice yield) (%)	6.14	3.49

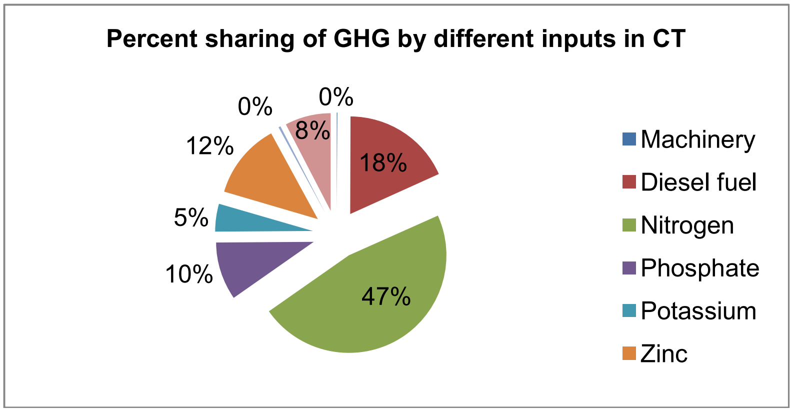

Fig. 1. Percent sharing of GHG by different inputs in CT

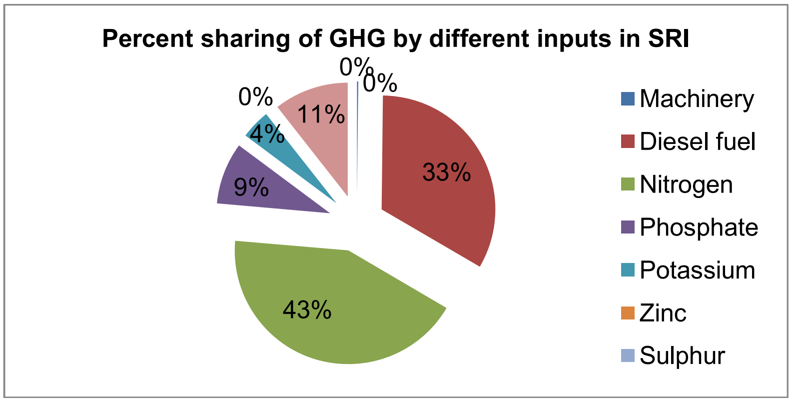

Fig. 2. Percent sharing of GHG by different inputs in SRI

in SRI. Total green house gas emission in Conventional transplanting was 834.85 kg$CO_2$$ha^{-1}$ and emitted 82.8% more than SRI (456.69 kgCO_2 ha^{-1}) method of cultivation. Green house gas emission per unit of output was 6.14% for CT whereas it was 3.49% in case of SRI.

4. CONCLUSION

High inputs and cost make the rice cultivation difficult in resource stricken areas. Besides, environmental concernment is a major issue in agricultural production system as agriculture is one of the major contributors to environmental pollution. Since conventional method of rice cultivation is energy intensive system, farming community has to shift to low input intensive rice cultivation system, i.e. SRI which is not only superior on the view oftotal energy consumption, net energy, energy use efficiency, energy productivity, energy intensity and energy profitability but also in terms of green house gas emission and grain yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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