Energetics of Raising Varying Duration Rice Varieties under Different Establishment Methods

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A B S T R A C T

Increasing farm labor scarcity and depletion of natural resources such as water are posing threats to the sustainability of traditional Puddled Transplanted Rice (PTR) system in Eastern India. Dry-seeded rice (DSR) or Non-Puddled Transplanted Rice (NPTR) could be used as an alternative to PTR. The use and cost of energy in agriculture have increased, making it necessary to make current agricultural practices more energy efficient. To achieve this, energy indices of rice establishment methods and varying duration rice varieties have been analysed in the present investigation. Fertilizer use accounted for the maximum input energy consumption, accounting for 51.8%, 46.1% and 39.9%, respectively, in DSR, NPTR and PTR system, followed by human labor. The DSR system was more energy efficient with Energy Use Efficiency of 9.6 compared to 8.6 and 7.5 in NPTR and PTR, respectively. The maximum Energy productivity of 0.32 kg MJ^{-1} and profitability of 8.6 were recorded in DSR. The lower value of specific energy (3.13 MJ kg^{-1}) under DSR indicated lower amount of energy requirement to produce unit grain yield. Cultivar duration groups did not differ significantly for total energy output and energy indices during both the years. However, cv. 'Swarna' had higher total energy consumption than cv. 'Arize 6444' and 'Arize 6129'.

Introduction

Energy plays a vital role in national development. It provides major vital services that improve human conditions *viz.* fuel for cooking, light for living, motive power for transport and electricity for modern communication. Agriculture is an energy user and energy supplier in the form of bioenergy the agricultural sector requires energy as an essential input to production (Lal *et al.,* 2013), enhancing food security, adding value (Karimi *et al.,* 2008), and contributing to rural economic development (FAO, 2000). Demand of energy by the agricultural sector to meet the food demand in worldwide of more than 7 billion people results in detrimental effects on the environment and the health of the farmers. If the energy in agricultural sector is used judiciously, it will

not only reduce the environmental impacts in terms of green house gases (GHG) emissions and other hazardous effects but will also lead to a desirable sustainable agriculture (Dalgaard *et al.,* 2001; Nasso *et al.,* 2011). At present, the productivity and profitability of agriculture depends on energy consumption (Alam *et al.,* 2005; Esengun *et al.,* 2007). A higher input of energy accounts for higher energy costs, which significantly reduces the net return of the farms and is a challenging issue for the policy makers. In many advanced agricultural systems, an increase in yield is clearly the result of an augmented energy input that is directly related to the use of improved crop management practices and the introduction of high-yield crop varieties. In most developing nations like India, both expansion of arable land and increase in total production are required, which occur via the use of efficient crop management practices (Faidley, 1992).Transplanting is the most popular method of rice establishment in irrigated areas. This method, however, has high water and labor requirements. In recent years, the direct seeding and transplanting in non-puddled condition has been promoted as a replacement for transplanting to address the problem of higher energy use in land preparation, puddling, irrigation etc. Therefore, increased energy efficiency in agricultural production system posed a challenge for the researchers and policymakers. Identification of energy-efficient rice cultivation system is important for food security and sustainable intensification.

Materials and Methods

The experiment was conducted at Agronomy Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha during *Kharif* season of 2014 and 2015. The experimental area is located at Bhubaneswar, Odisha, India with latitude of

20^0 15'N, longitude of 85^0 52'E and altitude of 25.9 m above mean sea level. The station falls under the East and South Eastern Coastal Plains Agro-climatic Zone of Odisha as per NARP classification (AZ 63) and Agro Ecological Sub Region (AESR) 18.4 of NBSS & LUP classification. The total rainfall received during *Kharif* season (June to November) for the year 2014 and 2015 was 1328.8 mm and 851.1 mm, respectively. The minimum and the maximum temperature ranged from 18.0^0C to 36.6^0C during 2014 and 20.1 C to 36.2 C during 2015. The relative humidity ranged from 87 to 95% in morning and 44 to 82% in evening during 2014 and 88 to 93% in morning and 55 to 77% in evening hours during 2015.The soil at the experimental site was sandy loam.

The experiment was laid out in split plot design with three crop establishment methods viz. direct seeded rice (DSR), non-puddled transplanted rice (NPTR) and puddled transplanted rice (PTR) allocated to main plots and three cultivar duration groups viz. short duration ('Arize 6129'), medium duration ('Arize 6444') and long duration ('Swarna') allotted to sub plots and replicated thrice. The recommended dose of fertilizers was 120 kg N, 60 kg P_2O_5,60kg K_2O and 5 kg Zn/ha.The basal dose of 24 kg N and full dose of phosphorus, potash and zinc was applied as basal in the form of DAP, MOP and zinc sulphate before sowing in DSR and final cultivation in NPTR and PTR. Then four top dressings of N were done at fortnight interval with 24 kg N per split applied in the form of urea starting at tillering stage and the last top dressing coinciding with the panicle initiation stage. The experimental field was initially dry ploughed with tractor drawn disc harrow followed by cultivator and rotavator operations to get fine tilth. Laser leveling was done to get perfect leveling which helps in maintaining plant population especially in NPTR, minimises time for irrigation and

reduces irrigation input and facilitates more efficient operations by farm machinery. For preparing the field under Puddled Transplanted Rice (PTR), the ploughed field was given flooded irrigation. Then the field was puddled well with cage wheel and leveled with wooden leveling board. Under Non-Puddled Transplanted Rice (NPTR) field was initially dry ploughed with tractor drawn cultivator followed by rotavator to get fine tilth. Thereafter, the ploughed field was given a surface wetting with 50 mm of water which was just sufficient to soak the soil for smoother transplanting of seedling. In dry seeded rice (DSR), plots were initially dry ploughed with tractor drawn cultivator followed by rotavator to get fine tilth.

Methods of energy budgeting

The energy analysis in the study compared the energy performance of different crop establishment methods with varying duration rice cultivars managed according to different input intensities. Energy fluxes of the cropping systems were estimated using crop management (machinery operations and amount of inputs used) and grain production records along with by-products. Inputs and outputs were converted from physical to energy unit measures through published conversion coefficients given in Table 1. Energy equivalents for all inputs were summed to provide an estimate of total energy inputs. Energy output from the economic yield (grain) and by-products was calculated by multiplying the amount of production by its corresponding energy equivalent. On the basis of energy input and output; net energy returns, energy use efficiency, energy efficiency ratio, specific energy, energy productivity and energy profitability were calculated by using the following formulae as suggested by Mittal and Dhawan (1988) and

Burnett (1982). Various energy use indices were computed by using following formula.

Net energy return (MJ.ha^{-1})= Total Output Energy (MJ.ha^{-1}) - Total Input Energy (MJ.ha^{-1})

Energy use efficiency = Total Output Energy (MJ.ha^{-1})/Total Input Energy (MJ.ha^{-1})

Energy efficiency ratio = Total Output Energy in main product (MJ.ha^{-1})/Total Input Energy (MJ.ha^{-1})

Specific energy (MJ.kg^{-1}) = Total Input Energy (MJ.ha^{-1})/Total main product yield (kg.ha^{-1})

Energy productivity = Total main product yield (kg.ha^{-1})/Total Input Energy (MJ.ha^{-1})

Energy profitability = Net energy return (MJ.ha$^{-1)}$)/Total Input Energy MJ.ha^{-1}

Results and Discussion

Energy input and source wise energy use pattern

The Puddled Transplanted Rice (PTR) recorded the maximum of 22,167MJ.ha^{-1} total input energy use followed by 19,225MJ.ha^{-1} in case of Non-Puddled Transplanted Rice (NPTR) (Table 2). Direct Seeded Rice (DSR) recorded the minimum total input energy. The maximum energy was consumed in terms of chemical fertilizers followed by irrigation, human labour, fuel (diesel), electricity, plant protection and seed in PTR, but the trend was different in DSR and NPTR system. Energy use by fertilizers represented the major part of energy use accounting for 39.9% to 51.8% in all the establishment methods. The energy consumption by irrigation source was the minimum under DSR due to a comparable low water requirement during the crop growth period.

Table.1 Energy equivalents of inputs and outputs for agricultural production

Component	Energy equivalent (MJunit^{-1})	Reference
Direct Energy		
Labor (hr)	1.96	Mittal and Dhawan (1988)
Diesel (lt)	56.31	Mittal and Dhawan (1988)
Electricity (kWh)	11.93	Mittal and Dhawan (1988)
Indirect energy		
Seed (kg)	14.7	Nassiri and Singh (2009)
N (kg)	60.6	Kuswardhani *et al.* (2013)
P$_2$O$_5$ (kg)	11.1	Chaudhary *et al.* (2009)
K$_2$O (kg)	6.7	Chaudhary *et al.* (2009)
ZnSO$_4$ (kg)	20.9	Taewichit (2012)
Herbicide (kg)	288	West and Marland (2002)
Insecticide (kg)	237	West and Marland (2002)
Fungicide (kg)	196	West and Marland (2002)
Irrigation (m3)	1.02	Singh *et al.*(2008)
Machinery (hr)	62.7	Dagistan *et al.* (2009)
Output energy		
Grain (kg)	14.7	Nassiri and Singh (2009)
Straw (kg)	12.5	Kitani (1999)

Table.2 Effect of establishment methods and cultivar duration groups on energy use (MJ ha^{-1}) from different sources (mean of two years)

Particular	Seed	Fertilizer	Agro-chemicals	Electricity	Fuel	Machinery	Irrigation	Human Labour	Total
Establishment method									
DSR	441 (2.58)*	8,863 (51.80)	2,101 (12.28)	1,133 (6.62)	594 (3.47)	339 (1.98)	1,250 (7.30)	2,389 (13.96)	17,109 (100)
NPTR	441 (2.29)	8,863 (46.10)	1,583 (8.23)	1,432 (7.45)	1,439 (7.48)	-	2,688 (13.98)	2,781 (14.46)	19,225 (100)
PTR	441 (1.99)	8,863 (39.98)	1,583 (7.14)	1,730 (7.80)	2,033 (9.17)	-	4,769 (21.51)	2,749 (12.40)	22,167 (100)
Cultivar									
Arize 6129	441 (2.31)	8,863 (46.33)	1,430 (7.48)	1,432 (7.48)	1,355 (7.08)	113 (0.59)	2,863 (14.96)	2,634 (13.77)	19,131 (100)
Arize 6444	441 (2.30)	8,863 (46.24)	1,430 (7.46)	1,432 (7.47)	1,355 (7.07)	113 (0.59)	2,898 (15.12)	2,634 (13.74)	19,166 (100)
Swarna	441 (2.18)	8,863 (43.86)	2,406 (11.91)	1,432 (7.09)	1,355 (6.71)	113 (0.56)	2,946 (14.58)	2,650 (13.11)	20,205 (100)

*Figures in parentheses indicate percentage contribution to total energy input

Table.3 Effect of crop establishment methods and cultivar duration on energetics of *Kharif* Rice

Treatments	Energy input (x 10^3 MJ ha^{-1})		Energy output (x 10^3 MJ ha^{-1})		Net energy return (x 10^3 MJ ha^{-1})	
	2014	2015	2014	2015	2014	2015
Establishment methods						
DSR	17.15	17.07	164.63	163.96	147.47	146.89
NPTR	19.26	19.19	165.80	164.13	146.53	144.94
PTR	22.20	22.13	167.39	165.19	145.19	143.06
SEm±	0.01	0.02	3.35	3.35	3.36	3.34
CD (P=0.05)	0.03	0.07	NS	NS	NS	NS
Rice Cultivar						
Arize 6129	19.24	19.02	162.93	161.29	143.69	142.26
Arize 6444	19.24	19.09	167.63	165.42	148.39	146.33
Swarna	20.14	20.27	167.25	166.56	147.12	146.29
SEm±	0.01	0.01	2.85	3.16	2.85	3.16
CD (P=0.05)	0.02	0.04	NS	NS	NS	NS

Table.4 Energy indices as influenced by crop establishment methods and cultivar duration

Particulars	Energy use efficiency		Energy efficiency ratio		Specific energy (MJ kg^{-1})		Energy productivity (kg MJ^{-1})		Energy profitability	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Establishment methods										
DSR	9.60	9.61	4.68	4.75	3.15	3.11	0.32	0.32	8.60	8.61
NPTR	8.61	8.56	4.28	4.35	3.44	3.39	0.29	0.30	7.61	7.56
PTR	7.54	7.46	3.82	3.87	3.85	3.83	0.26	0.26	6.54	6.46
SEm±	0.18	0.18	0.09	0.09	0.08	0.08	0.01	0.01	0.18	0.18
CD P=0.05)	0.74	0.71	0.37	0.38	0.32	0.31	0.02	0.03	0.74	0.71
Rice Cultivar										
Arize 6129	8.56	8.58	4.17	4.25	3.56	3.51	0.28	0.29	7.56	7.58
Arize 6444	8.80	8.77	4.36	4.42	3.41	3.37	0.30	0.30	7.80	7.77
Swarna	8.39	8.29	4.26	4.30	3.48	3.45	0.29	0.29	7.39	7.29
SEm±	0.16	0.17	0.08	0.09	0.06	0.07	0.01	0.01	0.16	0.17
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The percentage contribution of energy through human labor was the maximum in NPTR due to manual transplanting instead of mechanical transplanting. The contribution to total input energy through machinery was only found in DSR due to sowing by seed drill, whereas the consumption of energy in the form of fuel was higher in PTR followed by NPTR due to more numbers of ploughing and puddling operations. Energy consumption in the form of plant protection measures was the maximum in DSR followed by NPTR and PTR. Among cultivar duration groups, the maximum energy was consumed in terms of

fertilizers followed by irrigation, human labor, agro-chemicals, electricity, fuel, seed and machinery, but the trend was same in all the cultivars. The total input energy was the maximum of 20,205 MJ.ha^{-1} in cv. 'Swarna' followed by cv. 'Arize 6444' (19,166 MJ.ha^{-1}) and cv. 'Arize 6129' (19,131 MJ.ha^{-1}).

Energy input-output relationship

Based on the grain and straw yield, treatment wise energy production was calculated. Establishment methods influenced energy input significantly in both the seasons with higher input under PTR (Table 3). The PTR recorded energy input of 22.20x 10^3 MJ ha^{-1} and 22.13 x 10^3 MJ ha^{-1} in the 1st and the 2nd year, respectively. The maximum total output energy of 167.39 x 10^3 MJ ha^{-1} and 165.19x 10^3 MJ ha^{-1} were recorded during 2014 and 2015, respectively in Puddled Transplanting Rice (PTR) followed by NPTR and DSR. Establishment methods had no significant influence on net energy return, but, the value was higher in DSR followed by NPTR and PTR. Among the cultivar duration groups, cv. 'Swarna' had significantly higher total energy requirement in both the years amounting to 20.14 x 10^3 MJ ha^{-1} and 20.27 x 10^3 MJ ha^{-1}, during respective years. In terms of total energy output and net energy return, the cultivars had no significant difference, whereas, the higher value was found in cv. 'Swarna'.

Energy indices

Energy use efficiency, energy efficiency ratio, specific energy, energy productivity and energy profitability were calculated for each treatment separately (Table 4). This enabled comparing different management options in terms of energy use with reference to grain and straw yield, in order to identify the most energy efficient production system.

The establishment methods exerted significant influence on energy indices, but the cultivar duration groups failed to influence energy indices significantly during both the years.

The maximum energy use efficiency, energy efficiency ratio, energy productivity and energy profitability were found in DSR production system, whereas the minimum value of specific energy was recorded in DSR. Higher value of energy use efficiency, energy efficiency ratio, energy productivity, energy profitability and lower value of specific energy symbolized greater efficiency of DSR production system than NPTR and PTR in saving energy. The DSR recorded mean energy use efficiency, energy efficiency ratio, specific energy, energy productivity and energy profitability values of 9.61, 4.71, 3.13MJ kg^{-1}, 0.32kg MJ^{-1} and 8.61, respectively.

The following conclusions are be drawn from this study

The total input energy for the PTR, NPTR and DSR systems were 22.16 x 10^3MJha^{-1}, 19.23 x 10^3MJha^{-1} and 17.11x 10^3MJha^{-1}, respectively. The total net energy output was higher in DSR system (147.18 x 10^3MJha^{-1}) compared to the NPTR (145.74 x 10^3MJha^{-1}) and PTR (144.13 x 10^3MJha^{-1}). Among the cultivars cv. 'Swarna' and cv. 'Arize 6129' recorded the maximum and the minimum values, respectively.

Total energy output was the maximum in cv. 'Swarna' (166.91 x 10^3MJha^{-1}) followed by cv. 'Arize 6444' (166.53 x 10^3MJha^{-1}) and cv. 'Arize 6129' (162.11 x 10^3 MJha^{-1})

The use of fuel as a source of energy was higher in the PTR system (9.17 %) compared to the DSR system (3.47 %), which was due to the more numbers of

ploughing requirement for puddling operation. Fertiliser use accounted for the maximum energy consumption with a total contribution of 51.8%, 46.1% and 39.9%, respectively, in DSR, NPTR and PTR system.

The DSR system was more energy efficient with higher values of energy indices in the system compared to the NPTR and PTR system. The Energy Use Efficiency value for the DSR system (9.6) was higher than that of NPTR (8.6) and PTR (7.5). Similarly, the energy productivity and profitability values were higher in the DSR system. The cultivars had no significant effect on energy indices.

Acknowledgments

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