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Research Paper

Energy saving and profitability of rice (*Oryza sativa*) under mechanized and conventional system of rice intensification

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ABSTRACT

A field experiment was conducted during the rainy seasons of 2013 and 2014 at Hyderabad, Telangana, to evaluate the effect of mechanized and conventional system of rice (*Oryza sativa L.*) intensification. From the 2 years data, significantly higher gross energy output, net energy, energy-use efficiency, energy productivity and energy intensity were recorded with system of rice intensification (SRI) over mechanized system of rice intensification (MSRI). Energy-use efficiency, energy productivity and energy intensity recorded were significantly higher with irrigation at 3 days after disappearance of pounded water (DADPW) and these were at par with saturation treatment. Nitrogen application based on leaf colour chart (LCC) recorded higher gross energy output, net energy, energy-use efficiency, energy productivity and energy intensity in economic terms as compared to other nitrogen management practices. MSRI and SRI performed equally better with respect to benefit: cost ratio. Considerably higher gross and net returns were obtained with SRI as compared to MSRI. The labour saving was 21–25% higher with MSRI than SRI. Irrigation at 3 DADPW recorded significantly higher net returns and benefit: cost ratio, which was comparable with saturation treatment. Gross returns, net returns and benefit-cost ratio, were significantly higher with nitrogen application based on LCC, except soil test crop response based nitrogen application.

Key words : Disappearance of pounded water, Economics, Energetic, Leaf colour chart, Mechanized system of rice intensification

Traditional planting is the most conventional and common method of rice establishment under irrigated lowland ecosystems in India. Irrigated lowland rice not only consumes more water but also causes wastage of water. In recent years to address this problem, many methods of rice cultivation were developed, System of Rice Intensification (SRI) is one among them and it lessen the amount of water use without compromising the rice yield (Shanthappa *et al.*, 2016). There is ample scope to increase productivity of rice by manipulating the environmental conditions that could modify microclimate and soil conditions. SRI method of cultivation is slowly gaining momentum all over the world including India. With the core principle of sustainable agriculture that seeks to make the best use of nature's goods and services as functional inputs, SRI works by integrating processes such as reduced plant population, transplanting single young seedling, wider square planting, mechanical weeding with need based fertilizer application and optimum use of water for better growth especially soil aeration (Kumar and Shivay, 2004).

In India, the area under rice crop has been decreasing over the years due to various factors such as urbanization, migration of labour from agriculture to non agriculture sector, increased input and labour costs are seriously threatening the cultivation of rice (Yadav *et al.*, 2013). Manual transplanting rice is laborious and time consuming. Non availability of laboures for transplanting at appropriate time leads to late planting resulting in poor yield (Awan *et al.*, 2008). Rice transplanting manually requires about 30–35 man-days/ha, which is nearly 25% of the total labour requirement in rice production (Swain *et al.*, 2013). Under such situation, a less expensive and labour saving method of rice cultivation without reduction in grain yield is imperative. About 850 to 900 man-hours of labour is required for cultivating one hectare of rice, of which trans-

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planting, weeding and harvesting operations consume most of the labour force (60–80%) in the form of input energy (Singh *et al.,* 2013). Because of drudgery and less efficiency of labours, farm operations has decreased considerably and reducing overall profitability of the SRI method of cultivation. To compensate these problems stress on mechanization is the need of the hour. Therefore, the mechanical transplanting is one such indispensable input which not only facilitates timely completion of operations but also enhances the production potential, labour saving, energy efficiency, productivity and profitability of rice. Therefore, in this contest a field experiment was conducted to evaluate the energy productivity and economics of rice under mechanized system of rice intensification and conventional system of rice intensification.

MATERIALS AND METHODS

A field experiment was conducted on a clay loam soil at Indian Institute of Rice Research (IIRR) formerly Directorate of Rice Research (DRR), Rajendranagar, Hyderabad, Telangana during the rainy seasons of 2013 and 2014 to evaluate the energetic, productivity and economics of rice under mechanized system of rice intensification (MSRI) and conventional system of rice intensification (SRI). Rice variety 'Varadhan' (DRR Dhan 36) used in this study is a derivative of indica/japonica cross with mid early duration (120–125 days). The treatments consisted of two planting methods (mechanized system of rice intensification (MSRI) and system of rice intensification (SRI)) as main plot treatments, three irrigation regimes (saturation, 5 cm irrigation at three and five days after disappearance of ponded water) as sub-plot treatments and four nitrogen management practices (recommended dose of nitrogen (RDN)-100% through inorganic, 75% nitrogen from inorganic and 25% nitrogen from organic source, leaf colour chart (LCC) based nitrogen application and soil test crop response (STCR) based nitrogen application with target yield of 6.5 t/ha as sub-sub plot treatments and 3 times replicated with split-split plot design. Yangio-China paddy transplanter (self-propelled rice transplanter) was used in the experiment for transplanting. The transplanter is fitted with diesel engine and transplants seedlings from mat type nursery (18 days old seedlings) in eight rows (spacing 23.8 cm between rows and 15–16 cm between the plant) in a single pass. In conventional SRI, fourteen days old age seedlings were transplanted manually with the spacing of 25 cm × 25 cm between row and plant. The irrigation water was applied through plastic pipe from the source to the field directly and a water meter was used for measuring irrigation water.

The recommended dose of phosphorus @ 60 kg P_2O_5/ha as single super phosphate (SSP), potassium @ 40 kg K_2O/ha as muriate of potash (MOP) and $ZnSO_4$ @ 20 kg/ha was applied to all the treatments uniformly as basal. In LCC based nitrogen management, whenever the LCC values were found to be below the fixed critical level of 3, recommended quantity of nitrogen was applied @ 25 kg/ha and the basal dose of nitrogen was applied @ 30 kg/ha. Nitrogen was applied in 4-splits LCC based treatments, whereas in remaining treatments nitrogen was applied in 3-splits (Table 1). Nitrogen was applied in STCR based plots, by utilizing formulae of FN=42T–0.55 SN, where, FN, Fertilizer nitrogen (kg/ha); T, targeted yield (t/ha); SN, soil available nitrogen (kg/ha). The total amount of nitrogen fertilizers were applied for rice during both the crop seasons have been given in table 1.

The energy input was calculated as the summation of energy requirement for labour, farm machineries, seed, fertilizers and irrigation used in system and expressed in MJ/ha. Output energy from the main product (grain) and byproduct (straw) was calculated by multiplying the amount of production and its corresponding energy equivalent.

The energetics indices were calculated by using the following formulae.

$$\text{Energy-use efficiency (\%)} = \frac{\text{Gross energy output (MJ/ha)}}{\text{Total energy input (MJ/ha)}} \times 100$$

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Grain + straw yield (kg/ha)}}{\text{Total energy input (MJ/ha)}}$$

Table 1. Nitrogen applied (kg/ha) in nitrogen management practices at MSRI and SRI during rainy seasons of 2013 and 2014

Nitrogen management practice treatments	2013			2014		
	Inorganic	Organic*	Total	Inorganic	Organic*	Total
N_1, RDN (100% inorganic)	120	–	120	120	–	120
N_2, RDN (75% inorganic and 25% organic)	90	30	120	90	30	120
N_3, LCC based N application	130	–	130	130	–	130
N_4, STCR based N application (Target yield–6.5 t/ha)	145	–	145	150	–	150

*Organic source: Vermicompost (1.5% N) applied at 2 t/ha.

$$\text{Energy intensity (MJ/₹)} = \frac{\text{Gross energy output (MJ/ha)}}{\text{Cost of cultivation (/ha)}}$$

Net energy = Gross energy output (MJ/ha) – Energy input (MJ/ha)

The data obtained on various parameters were analysed statistically by using standard procedure given by Gomez and Gomez, (1984). Statistical significance was tested by F value at 0.05 level of probability and critical difference was worked out for comparison among the treatments.

Table 2. Cost of resources used in the present study

Source	Cost ₹
Adult man	200/day
Women	180/day
Paddy seeds	40/kg
Farm machinery (Tractor)	600/ha
Self propelled machines	700/ha
Thresher	500/ha
N	12.1/kg
P_2O_5	44/kg
K_2O	30/kg
Zinc sulphate	20/kg
Vermicompost	4/kg
Water	10 mm/ha
Paddy grain	13.1/kg
Paddy straw	1.5/kg

RESULTS AND DISCUSION

Grain and straw yields

Different crop establishment techniques under various irrigation and nitrogen treatments differed significantly. System of rice intensification (SRI) resulted in higher pooled grain (6.09 t/ha) and straw yields (7.18t/ha) over mechanized SRI (5.80 and 6.85 t/ha, respectively) (Table 3). Wider spacing and less competition under SRI method enabled the plants to grow vigorously and helped to utilize the essential nutrients important for plant growth and development, which led to higher tillering and dry matter production (Mohanty *et al*., 2014). Irrigation maintained at saturation level throughout the crop growth period produced higher pooled grain (6.22 t/ha) and straw yields (7.24 t/ha) but was at par with irrigation at 3 days after disappearance of ponded water (DADPW) over irrigation at 5 DADPW (Table 3). The increase in rice productivity under saturation might be due to favorable soil water balance under saturation, which enhanced growth and development of rice crop. This may be ascribed to vital role of water in the carbohydrate metabolism, protein synthesis, cell division, cell enlargement and partitioning of photosynthates to sink for improved development of growth

Table 3. Grain and straw yields cost of cultivation, gross returns, net returns and benefit: cost ratio of rice as influenced by planting methods, irrigation regimes and nitrogen management practices (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation (× 10^3₹/ha)	Gross returns (×10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit: cost ratio
Planting methods (M)						
M_1, MSRI	5.80	6.85	40.4	86.3	45.9	1.15
M_2, SRI	6.09	7.18	41.8	90.5	48.7	1.18
SEm±	0.04	0.03	–	0.45	0.45	0.01
CD (P=0.05)	0.23	0.19	–	2.76	2.76	0.06
Irrigation regimes (I)						
I_1, Saturation	6.22	7.24	42.3	92.3	50.0	1.19
I_2, 3 DADPW	6.13	7.22	41.5	91.1	49.6	1.21
I_3, 5 DADPW	5.49	6.59	39.5	81.8	42.3	1.09
SEm±	0.06	0.03	–	0.81	0.81	0.02
CD (P=0.05)	0.20	0.10	–	2.64	2.64	0.06
Nitrogen management practices (N)						
N_1, 100% RDN (inorganic)	5.67	6.75	38.9	84.4	45.5	1.17
N_2, 75% inorganic + 25% organic	5.94	6.98	47.1	88.3	41.2	0.87
N_3, LCC based nitrogen	6.15	7.15	39.2	91.3	52.1	1.33
N_4, STCR targeted yield 6.5 t/ha	6.03	7.19	39.2	89.7	50.5	1.28
SEm±	0.07	0.04	–	0.89	0.89	0.02
CD (P=0.05)	0.19	0.1	–	2.54	2.53	0.06
Interactions	NS	NS	–	NS	NS	NS

SRI, System of rice intensification; MSRI, mechanized system of rice intensification; DADPW, days after disappearance of ponded water; LCC, leaf colour chart; STCR, soil test crop response; NS, non-significant traits (Yoshida, 1981).

Application of nitrogen based on LCC and STCR produced considerably higher grain and straw yields by 8.47 and 5.82; 6.28 and 6.40% respectively as compared to RDN through inorganic source. Prescriptive nitrogen application in rice centered on crop demand and is precisely related to photosynthetic rate and biomass production. Application of fertilizers based on soil test availability of nutrients at critical physiological phases would have supported for better assimilation of photosynthates towards grain. Increase in grain yield can also be attributed to favourable effect in accelerating the growth and yield parameters of rice (Alam *et al*., 2013).

Energy–use efficiency and productivity

System of rice intensification without mechanization enumerated higher pooled energy productivity (0.704 kg/MJ), energy intensity (4.31 MJ/₹) and lower input energy (18.87×10^3 MJ/ha) as compared to MSRI. The pooled input energy was higher by 4.50% in MSRI as compared to SRI. This could be due to higher input energy of machine transplanter in MSRI, whereas labour energy used under SRI was lowest during the crop seasons. The SRI had higher pooled gross output energy by 4.82%, net energy by 6.02% and energy-use efficiency by 9.45% in comparison with MSRI due to higher grain and straw yields in SRI, which led to higher gross output energy and net energy. Higher grain and straw yield coupled with lower energy intake in terms of input energy in system of rice intensification was also reported by Jayadeva *et al*. (2010) and Babu *et al*. (2014). The lowest pooled energy productivity (0.642 kg/MJ) and energy intensity (4.26 MJ/₹) were observed with MSRI as compared to SRI due to higher cost of cultivation with lower output energy in MSRI.

Among irrigation regimes, water maintained at saturation level resulted in higher pooled input energy (19.67×10^3 MJ/ha), gross output energy (181.94×10^3 MJ/ha) and net energy (162.27×10^3 MJ/ha) followed by 3 DADPW than 5 DADPW, due to higher number and amount of irrigation water, which attributed to higher grain and straw yields in saturation treatment resulting in higher net energy. Significantly higher energy productivity was observed in irrigation at 3 DADPW (0.692 kg/MJ), which was at par with irrigation maintained at saturation level (0.686 kg/MJ). It could be attributed to increased grain and straw yield with same amount of input energy level. The energy productivity was 8.02 and 6.97% lower in 5 DADPW as compared to irrigation at 3 DADPW and saturation treatments of pooled means.

Among nitrogen management practices, the highest input energy was recorded with RDN (75% inorganic and 25% organic) as compared to other nitrogen management practices, due to higher input energy in vermicompost than inorganic fertilizer sources (Yadav *et al*., 2013). Application of nitrogen based on LCC and STCR recorded significantly higher gross output energy and net energy as compared to other nitrogen management practices. The higher gross output energy with LCC was attributed to maximum grain and straw yields, higher net energy due to less input energy and more energy-use efficiency (Alam *et al*., 2013). Likewise, LCC based N management practice recorded significantly higher pooled energy productivity (0.690 kg/MJ) and energy-use efficiency (9.32%) than other organic and inorganic N management practices due to higher input response for output in LCC based N application. Similarly, application of nitrogen based on LCC registered higher energy intensity in economic terms (4.58 MJ) than RDN (75% inorganic and 25% organic), but was at par with STCR based nitrogen application. This was mainly due to higher cost of cultivation coupled with lower output energy in RDN (75% inorganic and 25% organic) (Balakrishnan *et al*., 2010).

Economics

In mechanized SRI method of planting, pooled cost of cultivation was lower (₹40.4×10^3/ha) than SRI (₹41.8×10^3/ha) because labour requirement was reduced by 18–20 man-days/ha in MSRI which led to lower cost of cultivation than SRI. Rashid *et al*. (2010) and Sanjeev *et al*. (2014) also reported 21–25% saving of total labours in MSRI as compared to SRI method of cultivation. SRI method of cultivation resulted in higher pooled gross and net returns by 4.88 and 6.17% over MSRI. However, both the planting methods performed equally better with respect to B: C ratio.

Irrigation maintained at saturation recorded higher pooled cost of cultivation (₹42.3×10^3/ha), gross returns (₹92.3×10^3/ha) and net returns (₹50.0×10^3/ha) than irrigation at 5 DADPW. This could be due to higher number of irrigations applied to saturation treatment as compared to irrigation at 3 and 5 DADPW (Kumar *et al*., 2013 and Paul *et al*., 2013). Whereas, irrigation applied at 3 DADPW recorded significantly higher benefit: cost ratio (1.21) as compared to irrigation at 5 DADPW, but it was at par with saturation treatment. This might be due to higher grain and straw yields with lower cost of cultivation as compared to saturation, which led to higher net returns in irrigation at 3 DADPW.

Among the nitrogen management practices, application of RDN (75% inorganic and 25% organic) recorded higher cost of cultivation (₹47.10×10^3/ha) than other nitrogen management practices. Higher cost of cultivation might be due to higher cost of organic source

Table 4. Energy-use parameters of rice as influenced by planting methods, irrigation regimes and nitrogen management practices (pooled data of 2 years)

Treatment	Energy input ($\times 10^3$ MJ/ha)	Gross energy output ($\times 10^3$ MJ/ha)	Net energy ($\times 10^3$ MJ/ha)	Energy-use efficiency	Energy productivity (kg/MJ)	Energy intensity (MJ/₹)
Planting methods (M)						
M_1, MSRI	19.72	171.0	151.3	8.68	0.642	4.26
M_2, SRI	18.87	179.3	160.4	9.50	0.704	4.31
SEm±	–	0.27	0.27	0.01	0.001	0.01
CD (P=0.05)	–	1.63	1.63	0.08	0.005	0.03
Irrigation regimes (I)						
I_1, Saturation	19.67	181.9	162.3	9.27	0.686	4.32
I_2, 3 DADPW	19.32	180.3	161.0	9.35	0.692	4.37
I_3, 5 DADPW	18.90	163.1	144.2	8.65	0.641	4.16
SEm±	–	1.12	1.12	0.06	0.004	0.03
CD (P=0.05)	–	3.66	3.66	0.18	0.013	0.09
Nitrogen management practices (N)						
N_1, 100% RDN (inorganic)	18.07	167.8	149.7	9.29	0.688	4.31
N_2, 75% inorganic + 25% organic	20.24	174.6	154.4	8.63	0.639	3.70
N_3, LCC based nitrogen	19.29	179.7	160.4	9.32	0.690	4.58
N_4, STCR targeted yield 6.5 t/ha	19.58	178.4	158.8	9.11	0.675	4.54
SEm±	–	1.27	1.27	0.07	0.005	0.03
CD (P=0.05)	–	3.60	3.60	0.19	0.014	0.09
Interactions	–	NS	NS	NS	NS	NS

SRI, System of rice intensification; MSRI, mechanized system of rice intensification; DADPW, days after disappearance of ponded water; LCC, leaf colour chart; STCR, soil test crop response; NS, non-significant

(vermicompost), which led to higher cost of cultivation. The net returns registered significantly higher with LCC based N management practice (₹52.1 × 10^3/ha) than STCR and RDN with or without organic manure application. It may be attributed to less input cost and more economic efficiency. Likewise, LCC (1.33) and STCR (1.28) based N management recorded significantly higher benefit: cost ratio than other nitrogen management practices during both the years of study owing to higher grain and straw yields.

From the above findings, it can be concluded that, the gross energy output, net energy, energy-use efficiency, energy productivity and energy intensity in economic terms recorded were higher with SRI besides improved grain and straw yields and net returns over MSRI. Application of irrigation at 3 DADPW resulted in higher energy-use efficiency and productivity, net returns and benefit: cost ratio than other saturation treatments. LCC based nitrogen application found beneficial in achieving higher energy output, net energy, energy-use efficiency, energy productivity and energy intensity in economic terms as compared to other nitrogen management practices.

REFERENCES

Alam, M.M., Rezaul, K. and Ladha, J.K. 2013. Integrating best management practices for rice with farmers' crop management techniques: A potential option for minimizing rice yield gap. *Field Crops Research* **144**: 62–68.

Awan, T.H., Ali, I., Safdar, M.E., Ahmad, M. and Akhtar, M.S. 2008. Comparison of parachute, line and traditional rice transplanting methods at farmer's field in rice growing area. *Pakistan Journal of Agricultural Sciences* **45**(4): 432–438.

Babu, S., Singh, R., Avasthe, R.K., Yadav, G.S. and Chettri, T.K. 2014. Production potentional, economics and energetic of rice (*Oryza sativa*) genotypes under different methods of production in organic management conditions of Sikkim Himalayas. *Indian Journal of Agronomy* **59**(4): 602–606.

Balakrishnan, M., Ravisankar, N., Swamam, T.P. and Din, M. 2010. Influence of prickly sesban (*Sesbania cannabina*) intercropping in wet-seeded rice (*Oryza sativa*) on productivity, profitability, energetic and nitrogen balance under island ecosystem. *Indian Journal of Agricultural Sciences* **80**(1): 21–23.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agriculture Research*. John Wiley and Sons Publishers, New York. pp. 357–423.

Jayadeva, H.M., Setty, T.K.P., Bandi, A.G. and Gowda, R.C. 2010. Water use efficiency, energtics and economics of rice as influenced by crop establishment techniques and sources of nitrogen. *Crop Research* **39**(1, 2 and 3): 14–19.

Kumar, D. and Shivay, Y.S. 2004. System of rice intensification. *Indian Farming* (Special Issue) **54**(8): 18–21.

Kumar, S., Singh, R.S., Yadav, L. and Kumar, K. 2013. Effect of moisture regime and integrated nutrient supply on growth, yield and economics of transplanted rice. *Oryza* **50**(2): 189–191.

Mohanty, A.K., Islam, M., Kumar, G.A.K. and Kumar, A. 2014.

Enhancing rice (*Oryza sativa*) productivity through demonstrations of SRI method of cultivation in mid altitude region of Indo Himalayan belt of Sikkim. *Indian Research Journal of Extension Education* **14**(3): 88–92.

Paul, P.L.C., Rashid, M.A. and Paul, M. 2013. Refinement of alternate wetting and drying irrigation method for rice cultivation. *Bangladesh Rice Journal* **17**(1 and 2): 33–37.

Rashid, Z., Rasool, S., Rashid, M. and Inamullah, S. 2010. Mechanical transplantation of paddy. *Intensive Agriculture* **12**(6): 18–20.

Sanjeev, K., Kumar, S.U. and Manibhushan, 2014. Productivity and economics of rice–wheat cropping system as affected by methods of sowing and tillage practices in the eastern plains. *Journal of Agriculture Research* **1**(3): 145–150.

Shantappa, D., Kumar, M.R., Desai, B.K., Pujari, B.T., Tirupataiah, K., Koppalkar, B.G., Umesh, M.R., Naik, M.K. and Reddy, Y.K. 2016. Influence of establishment methods, irrigation water levels and weed management practices on growth and yield of rice (*Oryza sativa* L.). *Indian Journal of Agronomy* **61**(2): 174–178.

Singh, T.V, Kumar, M.R. and Viraktamath, B.C. 2013. Selective mechanization in rice cultivation for energy saving and enhancing the profitability. *Rice Knowledge Management Portal,* Indian Institute of Rice Research, Hyderabad, pp. 1–14.

Swain, S.K., Nayak, B.R., Khanda, C.M. and Dash, A.K. 2013. Effect of establishment methods on yield and economics of rice (*Oryza satavia* L.). *Madras Agricultural Journal* **100**(10–12): 803–805.

Yadav, S.K., Babu, S., Singh, Y., Yadav, G.S., Singh, K., Singh, R. and Singh, H. 2013. Effect of organic nitrogen sources and biofertilizers on production potential and energy budgeting of rice (*Oryza sativa*)-based cropping systems. *Indian Journal of Agronomy* **58**(4): 459–464.

Yadav, S.N., Chandra, R., Khura, T.K and Chauhan, N.S. 2013. Energy input output analysis and mechanization status for cultivation of rice and maize crops in Sikkim. *Agricultural Engineering International: CIGR Journal* **15**(3): 108–116.

Yoshida, S. 1981. Fundamentals of rice crop science. *International Rice Research Institute*. Los Banos, Phillipines. pp. 30–39.