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Research Paper

Production potential, economics and energetics of rice (*Oryza sativa*) genotypes under different methods of production in organic management conditions of Sikkim Himalayas

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ABSTRACT

Field experiments were conducted at Research Farm, ICAR Sikkim Centre during two consecutive rainy seasons (*kharif*) of 2012 and 2013 with the objective to select the efficient methods and rice (*Oryza sativa* L.) genotypes in terms of productivity, profitability and energetics for mid hill ecosystems of Sikkim Himalayas. The experiment was laid out in 3 times replicated split plot design, assigning 3 methods of rice production, viz. System of rice intensification (SRI), Integrated crop management (ICM) and Conventional planting (CP) to main plots and 6 rice genotypes, viz. 'Pusa Sugandh-2', 'Satyaranjan, Geetanjali', 'Rajendra Bhagwati', 'Krishna Bhog' and 'Shahsarang' in sub-plots. The results revealed that among the methods of rice production, significantly higher values of all the yield attributes {productive tillers/hill, panicle length (cm), panicle weight (g), grains/panicle, 1,000 grain weight (g)} and grain yield (3.97 t/ha) were recorded with SRI followed by ICM and conventional method of planting. The increase in yield with SRI was 25 and 55% higher over the ICM and conventional planting, respectively. Gross returns, net returns, benefit: ratio and energy use efficiencies were also higher under SRI. Amongst the genotypes, maximum values of yield attributing characters and grain yield (4.15 t/ha) were recorded with the 'Satyaranjan' which was significantly superior to other genotypes.

Key words: Energetics, Genotypes, ICM, Productivity, Rice, SRI

Rice is the one of the most important crop of Sikkim, however, its average productivity is quite low (37%) than the national average. Mountainous ecosystem of the state marred with low solar radiation, high disease and insect-pest incidence along with poor soil and crop management practices. Farmers of the state mainly grow transplanted puddled rice with traditional genotypes; hence crop yields are low, however, the quantum of resources used per unit of production is very high. Rice is a semi aquatic plantand uses approximately 5000 liters of water to produce 1 kg of rice under puddled condition and conventional methods of planting. Sustaining rice production under decreasing water availability and shrinking land area is becoming major challenge in mountain ecosystems. Energy is one of the most valuable inputs in production agriculture. Agriculture itself is energy user and energy supplier in the form of bio-energy (Alam *et al.*, 2005). Energy is one of the most important indicators of crop performance. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to determine the energy invested at every step of the production process (hence, identifying the steps that require least energy inputs), to provide a basis for conservation and to aid in making sound management and policy decisions. The possible way to increase the productivity of rice under organic management condition is through formulating better production technologies with location specific improved genotypes. The productivity of rice in the state can be increased by following the appropriate cultural practices along with high yielding rice genotypes. Avasthe *et al*. (2012) suggested that the system of rice intensification (SRI) holds a great promise in increasing the rice productivity under Sikkim conditions. In view of the above, field experiments were conducted at Research Farm, ICAR Sikkim Centre.

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MATERIALS AND METHODS

Field experiments were carried out during two consecutive rainy (*kharif*) seasons of 2012 and 2013 at agronomy experimental block of Research Farm, ICAR Research Complex for NEH Region Sikkim Centre, Tadong, situated at a latitude of 27°32' N and longitude of 88°60' E, altitude of 1300 meters amsl. Soil of experimental field was clay loam, belongs to order Inceptisol. The soil was low in available N (210.5 kg/ha), high in available P (26.30 kg/ha) and organic carbon (1.86%) and medium in available potassium (192.3 kg/ha). The amount of average rainfall received during the period of investigation was 1,579 mm, major part of which was received in the month of July and August. The experiment was laid out in 3 times replicated split-plot design, assigning 3 methods of rice production, viz. System of rice intensification (SRI), Integrated crop management (ICM) and Conventional planting (CP) to main plots and 6 genotypes, viz. 'Pusa Sugandh 2', 'Satyaranjan', 'Geetanjali', 'Rajendra Bhagwati', 'Krishna Bhog' and 'Shahsarang' in sub-plots. Recommended dose of nutrients were supplied through FYM and vermicompost (in terms of nitrogen equivalents). Field was irrigated, ploughed with bullock drawn plough followed by harrowing and levelling. The crop was planted on 5th and 7th July in 2012 and 2013, respectively. In SRI plots, 12-days old single seedling/hill, in ICM plots 18 days old seedling (2/hill) and in conventional rice, 30-days old seedlings (3/hill) were planted at a spacing of 20 cm × 20 cm, 25 cm × 20 cm and 20 cm × 15 cm, respectively. SRI and ICM plots were kept moist throughout the vegetative stage with required irrigation when the gap in the rains was long. However, in conventional planting (CP) all the plots were flooded with 7–10 cm standing water until the flowering stage. SRI and ICM treatments were weeded at 15 days interval up to maximum tillering stage.Weeding was done by cono-weeder in the SRI plots and by hand in CR plots thrice [15, 30 and 45 days after transplanting (DAT)]. The plot size was 4.0 m × 2.5 m for each treatment. All the genotypes of rice were grown as per recommended practices and harvested in the second week of November, except 'Rajendra Bhagwati' and 'Krishna Bhog', which were harvested in the first and last week of November in both the years, respectively. Effective tillers/hill was counted from randomly selected ten hills/plot. Length of the panicle was measured from a sample of ten panicles drawn at random from the marked plants. The length was measured from neck to the tip of the panicle and average panicle length computed. From the sampled 10 panicles which were used for panicle length were also used to record the weight of the panicles and mean panicle weight, grains were separated, cleaned and finally filled grain separated. The total number of grains for the 10 panicles randomly selected from each plot was counted and their average was computed. The 1,000-filled grains, taken from sampled panicles, were first counted and then weighed to compute the 1,000-grain weight. After harvesting, threshing, cleaning and drying the grain yield was recorded at 14% moisture. Straw yield was obtained by subtracting grain yield from the total biomass yield. Yield was expressed in t/ha. Cost of cultivation was computed based on the prevailing market prices of the inputs during the respective crop season. Gross returns were computed based on the grain and straw yields and their prevailing market prices during the respective crop season. Net returns were computed by subtracting cost of cultivation from gross returns.

Net returns (₹/ha) = Gross returns (₹/ha) – Cost of cultivation (₹/ha)

Benefit: cost ratio C = Net returns (₹/ha) / Cost of cultivation (₹/ha)

The input energy was divided into direct and indirect and renewable and non-renewable forms for final energy estimation (Hatirli *et al.,* 2006). The direct energy consists of diesel, human power and electricity, while the indirect energy contains seed, farmyard manure and machinery (Singh *et al.,* 2007). Total physical output referred to both grain/seed and by-product yields. Quantity/number of all inputs used in the form of labour, seed and manures were taken into consideration. To calculate the input energy it was converted to energy equivalents by multiplying their per unit energy equivalents. The farm produce (seed yield+straw yield) was also converted into energy in terms of energy output (MJ) using two year's average crop yield multiplied by their energy equivalents per unit. Based on the energy equivalents of the inputs and output, energy use efficiency, energy productivity, energy intensity in physical terms and energy intensity in economic terms were calculated.

Energy use efficiency = Gross energy output (MJ/ha)/Energy input (MJ/ha)

Energy productivity (kg/MJ) = [Total output (grain+straw) (kg/ha)]/Total energy input (MJ/ha)

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

Energy intensity in physical terms (MJ/kg) = Total energy input (MJ/ha)/Total output (grain+straw) (kg/ha)

Energy intensity in economic terms (MJ/) = Gross energy output (MJ/ha)/Cost of cultivation (₹/ha)

RESULTS AND DISCUSSION

Yield attributes and yield

Methods of rice production significantly influenced all the yield attributing characteristics (productive tillers/hill,

Table 1. Energy equivalent used in the study

Item	Energy equivalent	References
Man (adult)	1.96 MJ/h	Babu, 2012
Women (adult)	1.57 MJ/h	Yadav *et al.,* 2013
Bullock pair (small)	8.07 MJ/h	Yadav *et al.,* 2013
Rice grain	14.7 MJ/h	Yadav *et al.,* 2013
Rice straw	12.5 MJ/kg	Yadav *et al.,* 2013
Farm Yard Manure	0.30 MJ/kg	Yadav *et al.,* 2013
Farm machinery	62.7 MJ/h	Yadav *et al.,* 2013
Vermicompost	1.80 MJ/kg	Computed based on N content

Data was statistically analysed using the *F*-test following Gomez and Gomez (1984). LSD values at $P = 0.05$ were used to determine the significance of difference between treatment means.

panicle length, grains/panicle, panicle weight and 1,000-grain weight), grain and straw yields under organic management condition (Table 2). Pooled data of 2 years revealed that among the methods of rice production, system of rice intensification (SRI) recorded significantly higher values of productive tillers/hill (12.33), panicle length (24.7 cm) grains/panicle(110.3) and panicle weight (3.24 gm) and grain yield (3.97 t/ha) as compared to other methods of rice production which led to 25 and 55% increase in grain yield of rice over ICM and conventional planting respectively. This increase in grain yield under SRI could be attributed to profuse tillering, improved soil aeration achieved through the soil disturbance by cono-weeder operation, in addition to effective weed suppression (Thiyagarajan *et al.,*2005). These results are in conformity with findings of Singh *et al.* (2013). Amongst genotypes, 'Satyaranjan' recorded significantly higher values of productive tillers/hill (12.91), panicle weight (3.52 gm), grains/panicle (112.9), grain yield (4.15 t/ha) and straw yield (5.20 t/ha). However, panicle length (cm) remained at par with 'Rajendra Bhagwati', 'Krishna Bhog' and 1000 grain weight remained at par with 'Rajendra Bhagwati'. This might be due to variation in the yield potential of genotypes.

Economics

Pooled data of two years revealed that highest cost of cultivation was incurred with conventional planting method (34.9×10^3₹/ha) followed by ICM (32.5×10^3₹/ha) and SRI (30.4×10^3₹/ha), respectively (Table 2). This was 7.0 and 14.7% higher than ICM and SRI, respectively. It may be due to higher labour engaged during weed management and other cultural operations. Among the genotypes maximum cost of cultivation was observed with 'Krishna Bhog' (33.0×10^3₹/ha). This was due to the higher seed price. With respect to gross returns, net returns and benefit: cost ratio, among the methods of rice production, SRI recorded the higher values of gross returns (105.4×10^3/ha), net returns (74.9×10^3₹/ha) and benefit: cost ratio (2.46). This was due to lesser cost of cultivation and higher productivity as compared to other treatments. These results are in conformity with findings of Ishani *et al.* (2013) and Jayapalreddy and Shenoy (2013). Among

Table 2. Effect of production methods and genotypes on yield attributes, yield and economics of rice under organic management condition (pooled data of 2 years)

Treatment	Productive tillers/hill	Panicle length (cm)	Grains/ panicle	Panicle weight (g)	1,000-grain weight (gm)	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Method of production											
SRI	12.23	24.7	110.3	3.2	22.8	3.97	5.32	30.4	105.4	74.9	2.46
ICM	10.62	23.5	104.9	2.9	22.8	3.19	4.79	32.5	87.4	54.9	1.69
CP	6.52	22.2	95.8	2.7	21.8	2.55	4.27	34.9	71.1	36.2	1.04
SEm±	0.22	0.2	0.7	0.08	0.3	0.06	0.04	–	1.3	1.3	0.04
LSD (P=0.05)	0.62	0.5	2.1	0.2	0.8	0.16	0.13	–	3.9	3.9	0.12
Genotypes											
'Pusa Sugandha 2'	9.06	22.8	99.0	2.7	21.7	2.92	4.51	32.8	88.8	55.9	1.73
'Satyaranjan'	12.91	24.3	112.9	3.5	23.9	4.15	5.20	32.4	97.1	64.7	2.04
'Geetanjali'	11.00	23.3	101.8	2.9	22.6	3.00	4.61	32.6	89.7	57.1	1.77
'Rajendra Bhagwati'	11.56	23.7	107.8	3.1	22.9	3.67	5.31	32.4	91.9	59.6	1.88
'Krishna Bhog'	8.44	23.7	95.9	2.8	21.6	2.59	4.45	33.0	85.5	52.5	1.64
'Shahsarang'	9.78	22.9	104.9	2.7	22.2	3.08	4.68	32.5	74.6	42.2	1.32
SEm±	0.31	0.2	1.1	0.1	0.4	0.08	0.06	–	1.9	1.9	0.06
LSD (P=0.05)	0.88	0.6	3.0	0.3	1.1	0.23	0.18	–	5.4	5.4	0.17

SRI- System of Rice Intensification, ICM- Integrated Crop Management, CP- Conventional Planting the genotypes, 'Satyaranjan' proved better in term of gross returns (97.1 × 10^3₹/ha), net returns (64.7 × 10^3₹/ha) and benefit: cost ratio (2.04) over the other genotypes under study. This was due to higher productivity which resulted in higher values of these parameters.

Energetics

Pooled data of two years on energetic of rice production is presented in Table 3. Data revealed that energy input used in production methods showed marked variation. Maximum value of energy input used (9.74 GJ/ha) recorded with conventional planting. This was 3.9 and 7.9% higher over the ICM and SRI, respectively. It may be due to use of higher man-days for cultural practices in conventional planting. Higher energy input used under conventional planting was also reported by many workers (Yadav *et al*. 2013; Azarpour and Moraditochaee, 2013). However, similar energy input was recorded across the varietal treatments. Method of rice productioninduced marked variation in the gross and net energy output, energy use efficiency, energy productivity, energy intensity in physical terms and economic terms. SRI recorded significantly higher gross energy output (124.9 GJ/ha), net energy output (115.8 GJ/ha), energy use efficiency (13.82%), energy productivity (1.03 kg/MJ) and energy intensity in economic terms (4.11MJ/₹). This improvement in gross energy output, net energy output, energy use efficiency, energy productivity, energy intensity in economic terms was 37.2, 42.6, 47.9, 47.1and 57.5%higher over the conventional planting, respectively. However, lowest value of energy intensity in physical terms (0.99 MJ/kg) was recorded with SRI, which was 16.1and 31.7% lower than the ICM and conventional planting, respectively. The output energy was determined by the amount and quality of harvestable biomass (Gelfand *et al.,* 2010). In the present investigation maximum values of yield attributing characters were recorded under SRI, which resulted in higher grain and straw yields. Higher yield of rice under SRI over the ICM and conventional planting was also reported byKumar *et al.* (2009) and Singh *et al.* (2013). Energetics of rice production was also significantly influenced by genotypes (Table 3). Among the genotypes, 'Satyaranjan' recorded the significantly higher values of gross energy output (126.0 GJ/ha), net energy output (116.6 GJ/ha), energy use efficiency (13.50), energy intensity in economic terms (3.96 MJ/₹). Except energy productivity, this remains statistically at par with 'Rajendra Bhagwati'. However, energy intensity in physical terms was higher under 'Krishna Bhog' (1.38 MJ/kg). Energy use efficiency of any production system is directly related to the harvestable biomass. In the present study 'Satyaranjan' variety recorded the highest values of productivity, hence it reflected in energy parameters under study.

Based on 2 years study it was concluded that among the methods of production, system of rice intensification (SRI) and among the genotypes, 'Satyaranjan' was performing well under organic management condition of mid hill ecosystems of Sikkim Himalayas.

Table 3. Effect of production methods and genotypes on energetics of rice production under organic management condition (pooled data of 2 years)

Treatment	Energy input (GJ/ha)	Gross energy output (GJ/ha)	Net energy output (GJ/ha)	Energy use efficiency (%)	Energy productivity (kg/MJ)	Energy intensity in physical terms (MJ/kg)	Energy intensity in economic terms (₹/MJ)
Method of production							
SRI	9.03	124.86	115.82	13.82	1.03	0.99	4.11
ICM	9.36	106.65	97.28	11.39	0.85	1.18	3.28
CP	9.74	90.98	81.23	9.34	0.70	1.45	2.61
SEm±	–	1.28	1.28	0.14	0.01	0.01	0.04
LSD (P=0.05)	–	3.69	3.69	0.40	0.03	0.04	0.12
Genotypes							
'Pusa Sugandha-2'	9.38	99.24	89.86	10.63	0.80	1.29	3.05
'Satyaranjan'	9.38	126.02	116.64	13.50	1.00	1.02	3.93
'Geetanjali'	9.38	101.82	92.44	10.88	0.81	1.24	3.14
'Rajendra Bhagwati'	9.38	120.34	110.96	12.92	0.96	1.09	3.77
'Krishna Bhog'	9.38	93.75	84.37	10.06	0.76	1.38	2.88
'Shahsarang'	9.38	103.79	94.41	11.12	0.83	1.24	3.23
SEm±	–	1.82	1.82	0.20	0.01	0.02	0.06
LSD (P=0.05)	–	5.22	5.22	0.57	0.04	0.05	0.17

SRI- System of Rice Intensification, ICM- Integrated Crop Management, CP- Conventional Planting

REFERENCES

Alam, M.S., Alam, M.R. and Islam, K.K. 2005. Energy flow in Agriculture: Bangladesh. *American Journal of Environmental Sciences* **1**(3): 213–20.

Avasthe, R.K., Verma, S., Kumar, A and Rahman, H. 2012. Performance of rice (*Oryza sativa*) varieties at different spacing under system of rice intensification (SRI) in mid hill acid soils of Sikkim Himalayas. *Indian Journal of Agronomy* **57**(1): 32–37.

Azarpour, E. and Moraditochaee, M. 2013. A comparative study on energy use and cost analysis of rice varieties under traditional and semi-mechanized farming systems in north of Iran *http://dx.doi.org/10.5772/51165.*

Babu, Subhash. 2012. Recycling of sunflower residue for nutrients management in pigeonpea–sunflower cropping system. *Ph.D. Thesis,* Indian Agricultural Research Institute, New Delhi.

Gelfand, I., Snapp, S.S. and Robertson, G.P. 2010. Energy efficiency of conventional, organic and alternative cropping systems for food and fuel at a site in the U.S. Mid-west. *Environmental Science and Technology* **44**(10): 4,006–011.

Gomez, K.A. and Gomaz, A.A. 1984. *Statistical Procedures for Agricultural Research.* John Wiley & Sons, Singapore.

Hatirli, S.A., Ozkan, B. and Fert, C. 2006. Energy inputs and crop yield relationship in green house tomato production. *Renewable Energy* **31**: 427–38.

Ishani, A., Hazarika J.P. and Deka, N. 2013. A comparative economic analysis of SRI and traditional methods of rice cultivation in Assam. *Agricultural Economics Research Review*: 236–40.

Jayapalreddy, R. and Shenoy, N.S. 2013. A comparative economic analysis of traditional and system of rice intensification (SRI) rice cultivation practices in Mahabubnagar district of Andhra Pradesh. *International Journal of Scientific Research* **3**(10): 1–3.

Kumar, R.M., Surekha, K., Padmavathi, Ch., Subba Rao, L.V., Latha, P.C., Prasad, M. S., Ravindra Babu, V., Ramprasad, A.S., Rupela, O.P., Goud, V., Muthu Raman, P., Somashekar, N., Ravichandran, S. Singh, S.P. and Viraktamath, B.C. 2009. Research experiences on system of rice intensification and future directions. *Journal of Rice Research* **2**(2): 61–71.

Singh, H., Singh, A.K., Kushwaha, H.L. and Singh, A. 2007. Energy consumption pattern of wheat production in India. *Energy* **32**: 1848–854.

Singh, R.K., Singh, A.N., Ram, A., Prasad S.R. and Chauhan, R.K. 2013. Response of basmati (*Oryza sativa* L.) rice varieties to system of rice intensification (SRI) and conventional methods of rice cultivation. *Annals of Agricultural Research New Series* **34**(1): 50–56.

Thiyagarajan, T.M., Senthilkumar, K., Priyadarshini, R., Sundarsingh, J., Muthusankaranarayan, A., Hengsdijk, H. and Bindraban, P. S. 2005. Transitions in Agriculture for enhancing Water Productivity. (In): *Proceedings of an International Symposium held in Killikulam, Tamil Nadu, India* during 23–25, September 2003.

Yadav, S.K., Babu, Subhash, 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): 9–14.

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* Open access at http://www.cigrjournal.org **15**(3): 108–16.