Bangladesh J. Bot. **45**(5): 957-962, 2016 (December)

PRODUCTIVITY GROWTH RATE AND YIELD SUSTAINABILITY OF *ORYZA SATIVA* L. UNDER AEROBIC AND SUBMERGED ENVIRONMENTS USING SRI TECHNIQUE

US Gautam, AK Singh*[1], Jai Singh[2], P Mishra[3] and HK Niranjan[4]

Zonal Project Directorate, Zone-VII, ICAR, JNKVV campus, Adhartal, Jabalpur-482004 (MP), India

Key words: Oryzae satva, Productivity, Yield sustainability, Arobic and submerged, SRI

Abstract

A study was conducted under system of rice intensification (SRI) and non-SRI environment. A total of 195 and 77 technological demonstrations were conducted on SRI and non-SRI transplanting methods in various rice ecosystems. Mean rice yield of the technological demonstrations conducted on SRI was 5716 kg/ha, which was more than the mean yield of 3742 kg/ha under farmers' practice. However, in non-SRI demonstrations, the mean rice yield was 4136 kg/ha, which was more than the mean yield of 2941 kg/ha recorded under farmers' practice. Further, the mean rice yield of the SRI demonstrations was higher than that of the non-SRI demonstrations. The SRI technique is, thus, recommended for dissemination among the farming community for increased and sustained rice production.

Introduction

Rice is the stable food for almost half of the global population and 65 per cent of the Indian population (Vijayakumar *et al.* 2006, Sinha and Talati 2007). The principal rice-producing countries of the world are China, India, Japan, Bangladesh, Thailand, Myanmar, Vietnam, Brazil, South Korea, Philippines and the USA**.** In India, rice is currently cultivated on >44 million hectares, which accounts for >35 per cent of the total food-grains area and >23 per cent of the cropped area (Rajakumar 2013). With the current production of >91 million tons in India, rice accounts for little less than 50 per cent of the total food-grain production (Rajakumar 2013). Because of increasing population and per capita income, demand for rice is expected to rise at the rate of 1.6 per cent per year. However, area under rice cultivation is expected to decline to 40 million ha in the next 15 - 20 years (Shobharani *et al.* 2010). Rice consumes 3000-5000 liters of water to produce one kg of rice as against the requirement of only 900 liters for one kg of wheat. More than 80 per cent of the fresh water resources in Asia are used for agriculture and about half of which are used for rice production (Sujono 2007, Anas *et al.* 2011). Reduced amount of water in irrigated rice production has become a matter of global concern and water saving irrigation and higher water productivity techniques have received renewed attention (Bouman and Tuong 2001, Tuong and Bouman 2003). Available estimates indicate that fresh water availability in India will be reduced to one-third by 2025. Therefore, future increases in rice production would depend on improved water-use efficiency relative to rice.

*Author for correspondence: <singhak123@rediffmail.com>. [1]Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Vigyan Kendra, Sagar- 470002 (MP), India. [2]Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Vigyan Kendra, Sidhi-486661 (MP), India. [3]Department of Agricultural Statistics, Bidhan Chanda Krishi Vishwavidyalaya, Nadia, West Bengal, India. [4]Department of Agriculture Economics, AERC, JNKVV, Jabalpur (MP), India.

In Madhya Pradesh, total area under rice production in 2008-09 declined to 1682.30 thousands ha and only 1559.70 thousand tones production was achieved with a productivity of 927.12 kg/ha. The increased rice production of 1882.46 thousand tones in 2012-13 from 2774.95 thousands ha, with a productivity of 1474 kg/ha of the total rice area in Madhya Pradesh was achieved on account of better monsoon in the crop year. System of rice intensification (SRI), an alternative methodology to traditional flooded rice cultivation developed in the 1980s in Madagascar (Laulanié 1993), has been promoted around the world for more than a decade. The SRI constitutes a set of agronomic management practices for rice cultivation that can enhance yield (Kabir and Uphoff 2007, Namara *et al.* 2008, Senthilkumar *et al.* 2008). The SRI technology reduces water requirements (Satyanarayana *et al.* 2007) and offer opportunities to researchers and farmers to expand their understanding of potentials already existing in the rice genome. Keeping in view the above, a study was carried out to assess rice productivity, cultivation economics, rice yield growth rate and sustainability yield index of the technological front line demonstrations (FLDs) conducted under aerobic (SRI) and submerged (non-SRI) environments in the rice ecosystems of Madhya Pradesh.

Materials and Methods

Front line demonstrations were conducted using improved varieties and soil test based nutrient management by Krishi Vigyan Kendras (Farm Science Centres) under aerobic (SRI) and submerged (non-SRI) transplanting conditions in Madhya Pradesh during the years 2008-09 to 2012-13. Four genotypes, *viz.*, Pusa Sugandha 3, Pusa Sugandha 5, MR 219 and MTU 1010, were used in the technological demonstrations and three location-specific old varieties, *viz.*, IR 36, IR 64 and Kranti, with traditional transplanting system being used under farmers' practice were used as checks. The SRI methodology for raising rice production makes three main changes in irrigated rice cultivation: transplanting younger seedlings, preferably 9 - 14 days old before the plants enter their fourth phyllochron of growth, planting the seedlings singly rather than in clumps of 3 - 6 plants, and keeping the paddy soil moist but not continuously saturated during the plants' vegetative growth phase. System of rice intensification is, thus, referred to as a set of practices rather than a technology based upon a number of insights into how to create the best growing environments for rice plants as compared with other improved methods of rice cultivation under limited water resources. The selected genotypes had been extensively adopted because of high yield potential. In SRI and non-SRI methods, inputs applied were the same. Among the organic sources, farm-yard manure (FYM) was applied @ 5 t/ha. Soil test-based recommended dose of inorganic fertilizers was applied at the rate of 80 : 40 : 30 kg N, P_2O_5, K_2O/ha and 5 kg Zn/ha through urea, single super phosphate, muriate of potash and zinc sulfate, respectively. Nitrogen was given in three equal splits at basal, tillering, and panicle-initiation stages, while P, K and Zn were given as basal doses. A total of 195 and 77 technological demonstrations were conducted on SRI and non-SRI transplanting methods, respectively in three rice ecosystems covering 11 districts. The data were compiled and pooled for mean rice yield, net returns (NR), and benefit cost (BC) ratio to assess the rice productivity and economics. Data were analyzed for incremental BC ratio per ha, rice yield growth rates (SGR), sustainability yield index (SI) in SRI and non-SRI transplanting methods both in technological demonstrations and farmers' practice (FP). Correlation between cropping methods and factors of production (seed, fertilizer, manure, human labor, animal labor and rainfall) was also made in the study. The statistical tools, such as mean, kurtosis, skewness, standard error, standard deviation, sustainability index and correlation, were used for data analysis.

Results and Discussion

Table 1 shows that mean rice yield of 195 technological demonstrations conducted on SRI was 5716 kg/ha relative to the mean yield of 3742 kg/ha under farmers' practice. The mean rice yield of the technological demonstrations under SRI and SRI farmers' practice was higher than that of the non-SRI demonstrations and non-SRI farmers' practice. The highest yield (6141 kg/ha) was observed in 2009-10 and the lowest (5223 kg/ha) in the year 2008-09 under the technological demonstrations. The increase in grain yield under SRI was highlighted by Thiyagarajan *et al.* (2002, 2005). The rice yield in FP was highest (4199 kg/ha) in 2010-11 and lowest (3223 kg/ha) in 2008-09. The mean net return under demonstration was established as INR 29111/ha over the farmers' practice INR Rs. 17067/ha. Mean benefit cost (BC) ratio was recorded as 2.48 and 1.90 in SRI and farmers' practice, respectively. Mohanty *et al.* (2014) highlighted the results of 60 front-line demonstrations on SRI method which accounted for 25.44 per cent more yield over traditional random planting (TRP) method. Chowdhary *et al.* (2005) and Katambara *et al.* (2013) and Roy *et al.* (2012) reported that SRI was a promising new practice of growing rice that had proven to be very effective in saving water and increasing rice yields with livelihood security in many parts of the world. A number of formerly published studies on SRI have also shown enhancement in rice yield with the SRI methods (Namara *et al.* 2008, Satyanarayana *et al.* 2007, Sato and Uphoff 2007, Thakur *et al.* 2009).

Table 1. Mean rice yield, net return (NR) and BC ratio under system of rice intensification (SRI) environment.

Year	No. of demo.	Technological demonstrations (SRI)			Farmers practice		
		Yield (kg/ha)	NR (Rs/ha)	BC ratio	Yield (kg/ha)	NR (Rs./ha)	BC ratio
2008-09	35	5223	21205	2.34	3223	14132	1.74
2009-10	110	6141	20966	2.34	3707	11332	1.74
2010-11	9	5955	38000	2.70	4199	20000	2.00
2011-12	22	5581	29600	2.12	4140	17800	1.75
2012-13	19	5679	35784	2.91	3440	22069	2.26
Mean	39	5716	29111	2.48	3742	17067	1.90

The data given in Table 2 indicated that mean rice yield of 77 technological demonstrations conducted on non-SRI transplanting method was 4136 kg/ha relative to the mean yield of 2941 kg/ha under farmers' practice. The highest yield (5130 kg/ha) was recorded in 2009-10 and lowest (3044 kg/ha) in 2012-13 under the technological demonstrations. The rice yield in farmers' practice was highest (3390 kg/ha) in 2008-09 and lowest (2388 kg/ha) in 2011-12. Mean net return under demonstration was Rs. 35279/ha relative to the farmers' practice (INR 19184/ha). Mean benefit cost (BC) ratio in technological demonstrations under non-SRI transplanting method and farmers' practice was recorded as 2.63 and 2.0, respectively. Katambara *et al.* (2013) reported that more than 21 days old nursery transplanting at the rate of 3 - 4 seedlings per hill of local paddy varieties by using large amounts of water results in low yields, low water productivity and water-use efficiency. Many studies have reported that SRI saved 25 to 50% irrigation water without any yield penalty relative to conventional transplanting (Thiyagarajan *et al.* 2005, Thakur *et al.* 2009, Kumar *et al.* 2013).

The mean yield increase over FP in SRI and non-SRI was 53.9 and 41.6 per cent, respectively (Table 3). The highest yield increase (65.7%) was observed in 2009-10 and lowest (34.8%) in 2011-12 under SRI; however, in the case of non-SRI, highest yield increase (69.6%) was obtained in 2011-12 and lowest (6.5%) in 2008-09. The mean additional net return/ha under SRI was Rs. 10779 and Rs. 16095 for non-SRI transplanting method. The mean incremental BC ratio was Rs. 0.64 and Rs. 0.68 in SRI and non-SRI, respectively. The mean yield increase in SRI was higher than that of non-SRI demonstrations, which was also reflected in the year wise mean rice yields. On the other hand, in non-SRI demonstrations, variation in rice yield among the years was larger which influenced the year wise additional net returns.

Table 2. Mean rice yield, net return (NR) and BC ratio under non-SRI practice.

Year	No. of demo.	Technological demonstrations			Farmers practice		
		Yield (kg/ha)	NR (Rs./ha)	BC ratio	Yield (kg/ha)	NR (Rs./ha)	BC ratio
2008-09	12	3611	28267	2.67	3390	25468	2.09
2009-10	8	5130	27045	2.93	3260	8860	1.63
2010-11	18	4844	36839	2.42	3142	18793	1.77
2011-12	15	4051	58471	2.87	2388	22449	2.2
2012-13	24	3044	25773	2.28	2525	20351	2.1
Mean	15	4136	35279	2.63	2941	19184	2.0

Table 4. Comparison between system of rice intensification (SRI) and non-SRI rice cultivation over farmer practice.

Year	SRI			Non-SRI		
	Yield increase over FP (%)	Additional NR (Rs./ha)	Incremental BC ratio	Yield increase over FP (%)	Additional NR (Rs./ha)	Incremental BC ratio
2008-09	62.1	7073	0.6	6.5	2799	0.58
2009-10	65.7	9634	0.6	57.4	18185	1.3
2010-11	41.8	18000	0.7	54.2	18046	0.65
2011-12	34.8	11800	0.37	69.6	36022	0.67
2012-13	65.1	13715	0.65	20.6	5422	0.18
Mean	53.9	10779	0.64	41.6	16095	0.68

On the basis of above findings, we concluded that the technological demonstrations conducted on SRI; gave higher and stable rice yield with highest yield increase over the conventional practices than the non-SRI demonstrations. Further, the yield growth and sustainability was noted to be consistently greater under the SRI environment; hence, SRI-based rice production technologies can be adopted to enhance the productivity and yield sustainability of rice with water conservation. Further, there is a need to popularize the findings for its wider adoptability to benefit the farming community in India where large percentage of farmers are mainly small or marginal, who depends primarily on rice cultivation for their livelihoods.

References

Anas I, Rupela OP, Thiyagarajan TM and Uphoff N 2011. A review of studies on SRI effects on beneficial organisms in rice soil rhizospheres. Paddy and Water Environ. **9**: 53-64.

Bouman BAM and Tuong TP 2001. Field water management to save water and increase its productivity in irrigated low land rice. Agric. Water Management **49**: 11-30.

Choudhury BU, Singh AK and Bouman BAM 2005. Effect of establishment techniques on yield, crop water relationship in rice and wheat. Transitions in agriculture for enhancing water productivity: Proceedings of an International Symposium held in Killikulam, Tamil Nadu, India.

Kabir H and Uphoff N 2007. Results of disseminating the system of rice intensification with farmer field school methods in northern Myanmar. Expt. Agric. **43**: 4.

Katambara Z, Kahimba FC, Mahoo HF, Mbungu WB, Mhenga F, Reuben P, Maugo M and Nyarubamba A 2013. Adoption the (SRI) in Tanzania: A review. Agric. Sci. **4**(8): 369-375.

Kumar Mahender R, Raghuveerrao P, Somasekhar N, Surekha K and Padmavathi CH 2013. SRI - A method for sustainable intensification of rice production with enhanced water productivity. Agrotechnology. S11: 009. doi:10.4172/2168-9881.S11-009.

Laulanié H 1993. Le système de riziculture intensive malgache. Tropicultura **13**(1): 110-114.

Mohanty AK, Islam M, Kumar GA and K Kumar A 2014. Enhancing rice productivity through demonstrations of SRI method of cultivation in mid-altitude region of Indo-Himalaya belt of Sikkim. Indian Res. J. Extension Edu.**14**(3): 88-92.

Namara R, Bossio D, Weligamage P and Herath I 2008. The practice and effects of the system of rice intensification (SRI) in Sri Lanka. Intl. Agric. J. **47**: 5-23.

Pal S and Sahu PK 2007. On assessment of sustainability of crops and cropping system-some new measures. J. Sustainable Agric. **31**(3): 43-54.

Rajakumar R 2013. Economic and resource impact of System of Rice Intensification (SRI): an empirical study of Pudukkottai district in Tamil Nadu, India. Indian J. Natural Sci. **18**(3): 1311-1319.

Roy AK, Chakrabarty S, Chudali HD and Mahato BC 2012. SRI: An experimental in Puruliya under NAIP. Environ. and Ecol. **30**(4): 1280-1284.

Sato S and Uphoff N 2007. A review of on-farm evaluations of system of rice intensification methods in Eastern Indonesia. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources **2**(54): 1-12.

Satyanarayana A, Thiyagarajan TM and Uphoff N 2007. Opportunities for water saving with higher yield from the system of rice intensification. Irrig. Sci. **25**: 99-115.

Sahu PK, Kundu AL, Mani PK and Pramanicl M 2005. Sustainability of different nutrient combination in a long term rice-wheat cropping system. J. New Seeds **7**(3): 91-101.

Senthilkumar K, Bindraban PS, Thiyagarajan TM, Ridder N and Giller KE 2008. Modified rice cultivation in Tamil Nadu, India: Yield gains and farmers' (lack of) acceptance. Agric. Systems **98**: 82-94.

Shobarani N, Prasad GSV, Prasad ASR, Sailaja B, Muthuraman P, Numeera S and Viraktamath BC 2010. Rice Almanac - India. DRR Technical Bulletin No. 5. pp. 6-7, Directorate of Rice Research, Rajendranagar, Hyderabad.

Singh RP, Das SK, Bhaskar Rao VM and Narayana Reddy M 1990. Towards sustainable dryland Agricultural Practices. Tech. Bull. pp. 1 - 106, Central Institute for Dryland Agriculture, Hyderabad, India.

Sinha SK and Talati J 2007. Productivity impacts of the system of rice intensification (SRI): A case study in West Bengal, India. Agric. Water Management **87**: 55-60.

Sujono J 2007. Water Saving Irrigation on Paddy Fields for Increasing Productivity and for Flood Reduction. *In:* Wilson J (ed.). Water Resources Management. Honolulu, Hawaii, USA.

Thakur AK, Uphoff N and Antony E 2009. An assessment of physiological effects of system or rice intensification (SRI) practices compared with recommended rice cultivation practices in India. Expt. Agriculture. pp. 1-22.

Thiayagarajan TM, Velu V, Ramasamy S, Durgadevi D, Govindarajan K, Priyadarshini R, Sudhalakshmi C, Senthilkumar K, Nisha PT, Gayathry G, Hengsdijk H and Bindraban PS 2002b. Effects of SRI practices on hybrid rice performance in Tamil Nadu, India. *In:* Water-wise rice production, International Rice Research Institute (Manila, Philippines) IRRI and Plant Research International (PRI). Bouman BAS, Hengsdijk, H, Hardy B, Bindraban PS, Tuong TP, Ladha JK (eds). pp. 119-127.

Thiyagarajan TM, Senthilkumar K, Priyadarshini R, Sundarsingh J, Muthusankaranarayan A, Hengsdijk H and Bindraban PS 2005. Transitions in Agriculture for enhancing Water Productivity. Proceedings of an International Symposium held in Killikulam, Tamil Nadu, India during 23-25, September 2003.

Tuong TP and Bouman BAM 2003. Rice Production in Water-scarce Environments. *In:* Water Productivity in Agriculture: Limits and Opportunities for Improvement, Kijne JW, Barker R and Molden D (ed). CABI publishing. Wallingford, UK (2003). pp. 53-67.

Vijayakumar M, Ramesh S, Chandrasekaran B and Thiyagarajan TM 2006. Effect of System of Rice Intensification (SRI) Practices on Yield Attributes, yield and water productivity of rice (*Oryza sativa* L.) Res. J. Agric. and Biol. Sci. **2**: 236-242.

(Manuscript received of 9 August, 2015; revised on 20 August, 2015)