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System of Rice Intensification (SRI): Packages of Technologies Sustaining the Production and Increased the Rice Yield in Tamil Nadu, India

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Abstract

System of Rice Intensification (SRI) is a holistic agro-ecological crop management technique seeking alternatives to the high-input oriented agriculture and one among the scientific management tool of allocating irrigation water based on soil and climatic condition to achieve maximum crop production per unit of water applied over a unit area in unit time. System of rice intensification was the main focus technology demonstrated by Water Technology Centre (WTC), Tamil Nadu Agricultural University (TNAU) under Irrigated Agriculture Modernization and Water Bodies Restoration and Management (TN-IAMWARM) Project. In general, an increase in rice productivity under SRI over the conventional system of rice cultivation was observed in all the demonstrations. The widespread adoption of SRI showed increasing trend in yield (from 28.3% in 2007-08 to 32.4% in 2010-11). The results of beneficiary wise analysis indicated that more beneficiaries reaped 40-50% yield increase followed by 20-30% yield increase over conventional. The data obtained from large scale demonstrations clearly indicated that the water requirement was less under SRI (885 mm) as compared to conventional (1180 mm). The demonstration of SRI technologies registered higher grain yield and Water Use Efficiency (WUE) of 6,406 kg ha^{-1} and 7.31 kg ha^{-1} mm^{-1}, respectively as compared to conventional (5,284 kg ha^{-1} and 4.51 kg ha^{-1} mm^{-1}). The water productivity in SRI was found to be 1,398 as against 2,274 lit. kg^{-1} in conventional irrigation.

Keywords: SRI; Water productivity; Square planting; Alternate wetting; Drying irrigation

Introduction

Rice is the predominant crop accounting nearly 65% of total irrigated area in Tamil Nadu. The rice cropping system uses water in a wide variety of ways, both beneficial and non-beneficial. Tamil Nadu is one of the water starving states in India where total water resource available is 44361 Million cubic meter (Mm^3) as against the demand of 51813 Mm^3 leaving a gap of 7452 Mm^3. Hence, it is necessary to develop suitable technologies that recognize and adequately address the challenges we face and are going to face in the years to come since achieving food security has been the overriding goal of agricultural policies. The intensified efforts to improve both crop and water productivity and subsequently the farmers' income have resulted in many efficient water management practices in wetland rice.

Among the production constraints, availability of irrigation water is a major one, since rice is a predominant crop in Tamil Nadu consumes 70% of the water available for agriculture. The gap between water supply and water demand for irrigated crops in Tamil Nadu is projected to reach 21,000 Mm^3 by 2025 [1]. Irrigation water is used inefficiently in lowland rice cultivation, whilst farms that do not have access to irrigation water experience water scarcity. Whenever the monsoon fails, lowland rice faces water scarcity, leading either to crop failure or poor crop yield. Although rice yields have shown increasing trend over the years, there is a need to economize the water use in rice production. Rice research in India during the last century has resulted in the development of important technologies, adoption of which has helped in keeping the rice production growth rate ahead of the population growth rate. However, the appalling paucity of water threatens the sustainability of the irrigated rice eco-system. Such water shortage in many rice-growing areas is prompting a search for production systems that use less water to produce rice. Although several strategies are being pursued to save water in irrigated rice ecosystems, water losses still remain high since all those systems use prolonged periods of flooding.

Under modern methods of rice cultivation, 3000-5000 l of water was used to produce one kilogram of rice [2]. A significant portion of the total water requirement for rice production is used for land preparation alone. In recent years, wherever water is scarce, deficit irrigation is being recommended if it is economically tenable. Keeping in view, the need to maximize the production and providing minimum sustainable income, water-intensive crops such as sugarcane and wetland rice are being given up or go for alternate crops in the areas of water scarcity in spite of their vital importance in meeting people's needs. Farmers have a need for irrigated rice-based systems with technologies that save water by improving water productivity. The intensified efforts to improve both crop and water productivity and subsequently the farmers' income have resulted in many efficient water management practices in wetland rice. System of Rice Intensification (SRI) is a holistic agro-ecological crop management technique seeking alternatives to the high-input oriented agriculture and one among the scientific management tool of allocating irrigation water based on soil and climatic condition to achieve maximum crop production per unit of water applied over a unit area in unit time by converting conventional agronomic principles synergistically into higher yield production process.

Genesis of SRI in Tamil Nadu

The components of SRI were first tested in Tamil Nadu Agricultural

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University (TNAU) in 2000 and later on in 2003 under adoptive research trails in two major river basins of Tamiraparani and Cauvery of Tamil Nadu. In terms of rice productivity, SRI method of rice cultivation has registered higher yield levels than the farmers' conventional method of rice cultivation. The results from the study conducted at Dharmapuri and Krishnagiri districts of Tamil Nadu showed an increase by 21.9% by SRI over conventional method in these districts and net income of the farmers increased from 15.30 to 42.40% by adoption of SRI. The partial budgeting analysis results revealed that SRI adoption would bring net gain to the tune of INR (Indian rupees).13725/- per ha [3]. After implementation and execution of the trials, the components *viz*., less seed rate 7.5 kg ha^{-1}, raising mat nursery, young seedling (14-15 days old), square and single seedling transplanting per hill in wider spacing (25 x 25 cm), mechanical weeding 4 times (10, 20, 30 and 40 DAT), limited irrigation and nutrient management through Leaf Colour Chart (LCC) were counseled for adoption. Initial adoption and spread remained low in Tamil Nadu from 2004 to 2006. Considering the lower acceptance and existing scope for adoption, TNAU included SRI as one of the water saving technologies in Irrigated Agriculture Modernization and Water Bodies Restoration and Management (TN-IAMWARM) Project funded by World Bank with the objective of increasing the both crop and water productivity in rice crop.

In a predominantly agricultural state like Tamil Nadu, there is an urgent need for intensifying efforts to improve productivity, and sustainable farm income. Long-term growth in agriculture depends in large part on increasing the efficiency and productivity of use of water. With these aspects in mind this project was formulated and implemented in rice crop to increase the use efficiency of applied water and rice production in Tamil Nadu through large scale demonstration of SRI as one of the objectives.

Materials and Methods

Tamil Nadu is the southernmost state of India, surrounded by Andhra Pradesh from the North, Karnataka and Kerala from the west, Indian Ocean from the south and Bay of Bengal from the East. Cape Comorin or Kanyakumari, the southernmost point of India lies in the state of Tamil Nadu. The state of Tamil Nadu roughly extends between the 8° 04' N latitude (Cape Comorin) and the 78° 0' E longitude. Geographically, Tamil Nadu is situated on the eastern side of the Indian Peninsula between the northern latitude of 8.5" and 13.35" and the eastern longitude of 76.15" and 80.20". The climate of Tamil Nadu is tropical in nature with little variation in summer and winter temperatures. Tamil Nadu gets all its rains from the North-east Monsoon between October and December, when the rest of India remains dry. The project area, Tamil Nadu is one of the driest states in India, averaging only 925 millimeters of rainfall in a year.

Tamil Nadu's geographic area can be grouped into 17 river basins (127 Sub Basins) a majority of which are water-stressed. The project was implemented from 2007 in IV phases (I, II, III and IV) including 63 sub basins Figure 1 System of rice intensification was the main focus technology demonstrated by TNAU under TN-IAMWARM Project in Tamil Nadu. During the first year (2007-08), SRI was demonstrated in 1311 ha including 1456 farmers (Phase I in 9 sub basins). Subsequently SRI demonstrations were extended in remaining 54 sub basins. The size of the study area varied from 0.5 to 1.0 ha. The types of soil in the study area were loamy to clay loam. The fertility status of the soil in the study area was medium in available nitrogen, low to medium in available phosphorus and medium to high in available potassium. The farmers were trained to adopt the five major components of SRI in

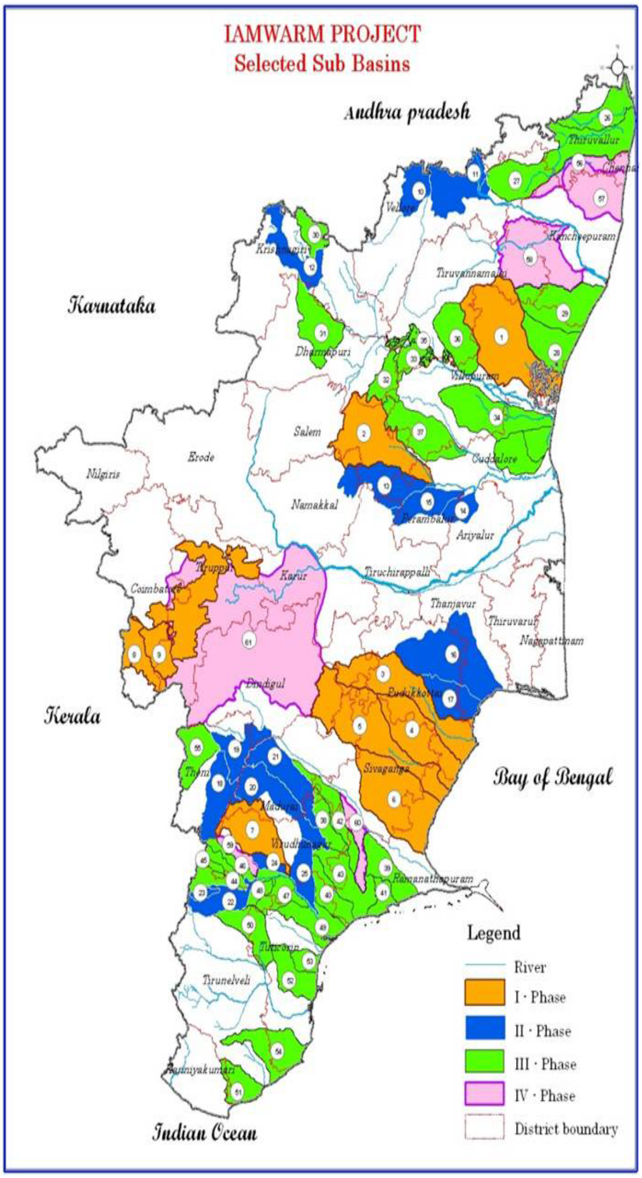

Figure 1: Selected Sub Basins of Tamilnadu Region.

demonstration fields. All the demonstration farmers were provided with inputs viz., seeds, cono weeder, and markers for square planting and LCC for nitrogen management. The major components demonstrated in SRI were less seed rate 7.5 kg ha^{-1}, raising mat nursery, young seedling (14-15 days old), square and single seedling transplanting per hill in wider spacing (25 x 25 cm), mechanical weeding 4 times (10, 20, 30 and 40 DAT), limited irrigation and nutrient management through LCC. Conventional method of cultivation was also demonstrated in the same field for comparison. The conventional system of cultivation includes adoption of 30-35 days old seedlings for planting and adoption of flood irrigation (continuous submergence with 5 cm depth of water) until harvest of the crop. Thus the project has provided an ambient platform for up-scaling the technology to every villages of the project area. The varieties used in the demonstrations were ADT 36, ADT 39, ADT 45, ASD 16, CR-1009, BPT 5204 and CORH-3. To study the effect of SRI on crop productivity water use studies were taken up in selected fields in demonstrations. Studies on water productivity with SRI were undertaken as a part of the project from 2007 to 2010. Studies were conducted in four locations, viz, Varaganadhi sub basin, Karumaniar sub-basin (Tirunelveli district, L1), Sevalaperiar sub-basin (Virudhunagar district, L2), Ongur sub-basin (Chengalpattu district, L3) and Nallavur sub-basin (Villuppuram district, L4) to compare the efficiency of SRI irrigation with the conventional irrigation (CI).

Alternate Wetting and Drying (AWD) irrigation system was the recommended water management practice under SRI. Under AWD irrigation system, water is applied to flood the field for a certain number of days after the disappearance of ponded water. The field was allowed to be dry for a few days between water applications. The number of days under AWD irrigation can vary from 1 day to more than 10 days. From planting to panicle initiation stage, field was irrigated to a depth of 2.5 cm after the previously irrigated water disappears and hairline cracks develop. After panicle initiation, irrigation was given to a depth of 2.5 cm one day after the previously ponded water disappears from the surface. At hairline crack stage, soil will not be completely dry, but yet moist. The measurement of irrigation water in fields was carried out by parshall flume.

Traditional mindset of farmers, lack of awareness, non-cooperation of planting labours, inability to deliver regulated irrigation water and non-availability of critical implements (Markers/Weeder) at appropriate season was the main bottlenecks identified in SRI adoption. Few innovative measures viz., exposure visit, field days, community nursery and field visit of high Command Government Officials were followed to expose SRI on large scale in the state. The SRI demonstrations were carried out in 17981 ha during the period from 2007 to 2011 in 19497 farmers' holdings.

Results and Discussion

The overall performance of SRI introduced at the project area of TN-IAMWARM indicated that an increase in rice productivity in SRI over the conventional system of rice cultivation was observed in all the years (Table 1). It is incredible that it has created such a remarkable consciousness among the rice growers of the State. The widespread adoption of SRI at field level showed an increasing trend in yield (from 28.3% in 2007-08 to 32.4% in 2010-11). Irrespective of years, the yield contributing parameters viz., No. of tillers per hill, No. of productive tillers per hill and grains per panicle were also higher in SRI demonstration than conventional practice (Table 2). Beneficiary wise analysis indicated that more no. of beneficiaries reaped 40-50% yield increase followed by 20-30% yield increase over conventional (Table 3).

Maximum grain yield achieved in SRI was due to higher Leaf Area Index (LAI) and light interception at wider spacing between plants gained from open plant structure. This resulted in higher LAI and greater leaf size leading to vigorous root system [4]. Whereas in conventional method at closer spacing between the rice plants, the number of panicles in unit area increases but with shorter panicles containing lesser grains resulted in lesser yield as shown in (Table 4). Planting of younger seedlings with optimal growing conditions is responsible for accelerated growth rate in SRI plants as these make possible to complete more phyllochrons before entering into their reproductive phase [5,6]. Completion of more phyllochrons at early seedling stage resulted in more number of tillers and effective tillers per hill. Moreover, younger seedlings have improved root characteristics like root length density and root weight after transplanting than do aged seedlings [7]. Rice grown under conventional system creates hypoxic soil condition and its roots degenerate under flooding, losing three-fourth of their roots by the time the plants reach the flowering stage [8]. Unflooded condition (alternate wetting and drying) in SRI, combined with mechanical weeding resulted in better aeration in the soil and greater root growth for better access to nutrients as compared to conventional planting. The SRI plants have deeper and stronger root systems, supported by intermittent irrigation and without physical

Year	Rice yield (kg ha^{-1})		% increase	Demo. Area (ha)	No. of Demonstrations
	SRI	Conventional			
2007-08	3710	2902	28.3	1311	1456
2008-09	4361	3237	33.3	2581	3029
2009-10	4588	3340	37.3	4000	5245
2010-11	4456	3365	32.4	10089	9767
Average/Total	**4454**	**3220**	**32.9**	**17981**	**19497**

Table 1: Performance of SRI demonstration in TN-IAMWARM Project in Tamil Nadu, India.

Year	No. of tillers per hill		No. of productive tillers per hill		No. of grains per panicle	
	SRI	Conventional	SRI	Conventional	SRI	Conventional
2007-08	22.7	10.6	18.6	8.0	135	118
2008-09	23.5	11.2	19.3	8.4	138	127
2009-10	25.8	12.5	21.2	9.4	152	134
2010-11	24.6	11.8	20.2	8.9	145	128
Average	**24.2**	**11.5**	**19.8**	**8.6**	**142**	**126**

Table 2: Effect of SRI on yield parameters (average values) in demonstrations of TN-IAMWARM Project in Tamil Nadu, India.

Year	% increase over conventional method of cultivation						Total
	<10	10-20	20-30	30-40	40-50	> 50	
2007-08	337	311	363	301	144	-	**1456**
2008-09	-	568	678	1004	387	392	**3029**
2009-10	71	567	543	331	2790	943	**5245**
2010-11	105	1158	2662	1918	1503	2421	**9767**
Total	**513**	**2604**	**4246**	**3554**	**4824**	**3756**	**19497**

Table 3: Beneficiary wise analyses of SRI farmers in TN –IAMWARM Project, Tamil Nadu, India.

barriers to root growth [9]. A number of previously published reports on SRI have showed enhancement of rice yield [10-13]. This study found SRI practices increasing grain yield at the range of 28.3 to 32.4%, from 4.954 t ha^{-1} to 6.583 t ha^{-1}, while utilizing fewer seeds and less water.

Water productivity of rice in SRI demonstrations

Irrigation studies conducted at Varaghanadhi sub-basin (Villupuram District, Tamil Nadu) during 2007-08 revealed that the irrigation water required for conventional method of rice cultivation was 9,204 m^{3}ha^{-1}, whereas it was 4,306 m^{3}ha^{-1} under SRI, thereby saving irrigation water to the tune of 41% (Table 5). Apart from the economy in water use, the alternate wetting and drying method of irrigation had a positive influence on yield and water productivity. The data clearly indicated that the water requirement was less under SRI (885 mm) as compared to conventional (1180 mm) (Table 6). SRI registered higher grain yield and WUE of 6,406 kg ha^{-1} and 7.31 kg ha^{-1} mm^{-1}, respectively as compared to conventional (5,284 kg ha-1 and 4.51 kg ha^{-1} mm^{-1}). The water productivity in SRI was found to be 1,398 litres kg^{-1} as against 2,274 litres kg^{-1} in conventional irrigation.

In SRI, Alternate Wetting and Drying (AWD) irrigation is practiced and it provides the water-loving rice plant with the primary conditions necessary for transplanting of single young seedling and mechanical weeding technologies leads to high yield. The AWD irrigation is a water-saving technology that lowland rice farmers are practicing to reduce their water use in irrigated fields. Shallow irrigation under AWD system could save water up to 40% without any yield loss. Irrigation intervals vary with soil texture. Fine textured clayey soil with higher field capacity need irrigation at longer intervals while coarse textured light soils with lower water holding capacity require irrigation frequently [14]. Practice of alternate wetting and drying under SRI had potential to save the water upto 24% and increment in grain yield to the tune of 71% [15,14]. The mechanisms for evoking these changes remain to be studied and determined in satisfactory detail.

Impact of SRI in rice production

Rice production and productivity in Tamil Nadu: Rice area in Tamil Nadu has been hovering around 18-20 lakh hectares for the past few years and except during 2007-08 (Figure 2). Remaining other years witnessed relatively larger positive deviation over the base year. The area under SRI is in the increasing trend in Tamil Nadu. In the past four years the SRI area has almost doubled and it was 4.2 lakhs during 2007-08 and rose to 10.01 lakhs in 2011-12. The share of SRI in total rice area increased from 23.48 (2007-08) to 50.0% (2011-12) during the above period. A favourable policy environment on promotion of SRI in the State could be cited as the prime reason for the increasing trend in area under SRI.

The rice production in Tamil Nadu has got stabilized due to upscaling of SRI on a mission mode approach. In the initial two years of SRI adoption, the percentage increase over the base year average (2002 to 2006) was less than 9% and it could be due to the occurrence of natural calamities like floods, unseasonal rainfall and cyclones. But, the last two years (2010-2011), the percentage increase in rice production has witnessed a conspicuous increase over the base period and the SRI coverage had been increased more than 35 to 50% in the total rice area (Figure 2). After the mass introduction of SRI in Tamil Nadu, the

Year	Rice area (Lakh ha.)	Area under SRI (Lakh ha.)	Productivity (kg ha^{-1})	Total production (lakh MT)
Base year (2002 to 2006)	17.54	-	2667	47.36
2007-08	17.89	4.20	2817	50.40
2008-09	19.32	5.38	2682	51.83
2009-10	18.46	6.49	3070	56.65
2010-11	19.06	8.50	3039	57.92
2011-12	19.05	10.01	3915	74.59

Base year – 5 year average (normal); Source: Season and Crop Report, Directorate of Economics and Statistics, GoTN, Chennai

Table 4: Impact of SRI on Rice area, Production, Productivity in Tamil Nadu.

Parameters	Conventional practice	SRI
Number of irrigations	18	13
Irrigation water (m^3 ha^{-1})	9,204	4,306
Rainfall (mm)	281	281
Total water used (m^3 ha^{-1})	12,014	7,116
Water saving (%)	-	40.8
Grain yield (kg ha^{-1})	5,120	7,528
Water productivity (kg m^{-3})	0.426	1.058

Table 5: Water requirement studies in SRI at Varaganadhi sub-basin during 2007-08.

Parameters	L1		L2		L3		L4		Average	
	SRI	CI	SRI	CI	SRI	CI	SRI	CI	SRI	CI
Water used (mm)	923	1,252	973	1223	827	1,148	818	1,098	885	1,180
Productive tillers hill^{-1}	31	20	48	31	36	23	39	24	38	24
Productive tillers m^{-2}	470	350	612	505	720	580	780	704	646	535
Grain yield (kg ha^{-1})	5,810	4,450	5,982	5,032	7,046	5,965	6,784	5,689	6,406	5,284
Water use efficiency (kg ha^{-1}mm^{-1})	6.28	3.55	6.14	4.11	8.51	5.20	8.29	5.18	7.31	4.51
Water productivity (l kg^{-1})	1,588	2,813	1,626	2,430	1,174	1,924	1,205	1,930	1,398	2,274

L – Locations; CI – Conventional Irrigation

Table 6: Water productivity of rice in SRI in selected sub-basins during 2010-11.

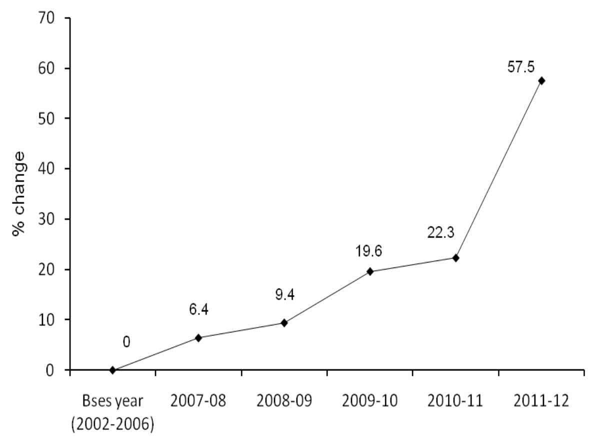

Figure 2: Percentage change in rice production over the base year of 2002 to 2006.

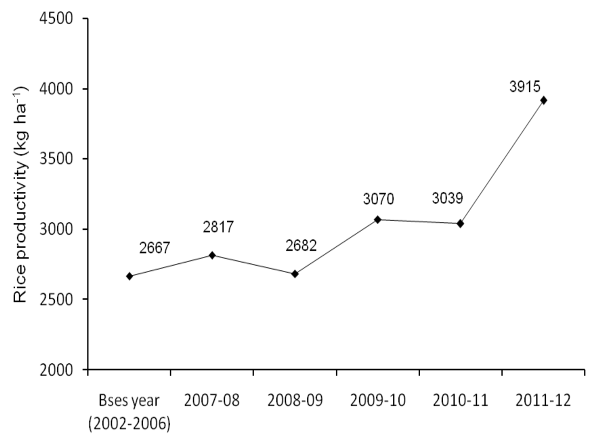

Figure 3: Rice productivity over the years (kg ha^{-1}).

yield levels had a positive trend except for year 2008-09 during that year the State experienced Nisha cyclone which devastated rice crops in 4.71 lakh hectares and there by seriously reducing the production and productivity levels (Figure 3). Even during the year 2007-08, the rice productivity levels were higher than the base year and the role of SRI could never be under estimated in the stress period caused by the heavy rains during December, 2007 and unusual rains during March 2008 in which nearly 1.68 lakh ha under rice crop had been directly affected. Later, the yield levels were consistently higher than 3.00 t ha^{-1} and it could be due to large scale adoption of SRI. It was also evidenced from the increased total rice production of the state. The favourable monsoon environment and SRI acreage led to increase in rice productivity during 2011-12.

Conclusions

System of rice intensification is not a fixed package of technical specifications, but a system of production with four main components, viz., planting method, weed control, soil fertility management and water (irrigation) management. Several field practices have been developed around these components. Drastic changes in the agronomic practices of SRI initially failed to build confidence amongst the farmers. Farmers themselves should become more experimental and entrepreneurial as a result of their engagement with SRI. This is not a technology like that of the Green Revolution, where farmers were expected simply to adopt a 'package.' SRI in its core conception involves adaptation rather than adoption, and farmers are expected to become more innovative. Though farmers who involved are committed to continue SRI, immense steps have to be taken to disseminate not only the technology but also the scientific facts behind the technology as a means of promoting SRI. It was realized that rice does not require flooded water or standing water, and it is enough to keep the soil moist from the demonstrations. The farmers using ground water will certainly realize a saving of water, time and electricity under SRI irrigation. If SRI is adopted in an entire command area, saved water encourage to bring more area under cultivation. Though SRI is a promising and successful technology in increasing the yield, it has not yet become a major method of cultivation owing to existing institutional and behavioural factors. Some of the principal challenges viz., resistance to accept SRI, non-co-operation of planting labourer, lack of training and extension facilities, absence of precise water management and non-availability of essential tools. If we address these issues, SRI would be a successful technology to boost the rice yields and the income of farmer.

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