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System of Rice Intensification Verses Conventional Rice System: Off-farm Field Studies

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ABSTRACT

With inevitable growth of demand for human and industrial needs, water available for agriculture will become scarcer in the future. India is a highly water-stressed country. Hence, India needs to invest in improving its water productivity, and any capacity to produce more rice with less water. System of Rice Intensification (SRI) has attracted much attention in increasing rice yield per unit area. For this study, fifteen farmers were selected those were practicing SRI technology by themselves during the Boro-cultivation season (January-April). The study was continued for three consecutive years 2012 to 14 on the same fields. In addition to the SRI plots, a similar size of non-SRI plot was maintained in conventional cultivation for comparison purpose. On an average, the non-SRI ight increased by 12%, number of tillers per square meter by 85%, number of reproductive tillers per hill by 286%, weight of panicle per hill by 139%, number of seeds per panicle by 41% and test weight by 26% due to SRI practice over the non-SRI practice. Average increment in straw and grain yield due to SRI over the non-SRI is 70% and 59% respectively. The physico-chemical and biological properties of soil improved due to SRI practice.

1. Introduction

Rice is life for millions of people in the world, particularly in developing countries. It is the main cereal for the majority of population in India. The global annual production of rice is 600-800 million tons (FAO, 2004)[3]. India has the largest area under rice in the world-about 44 million hectares (ha)—but its productivity is the way behind a dozen other countries. In contrast, China, the biggest producer of rice in the world, churns out 193 million tonnes of paddy on just 29.2 million ha, notching up yields of 6.61 tonnes per ha compared with 3.37 by India. Given the fact that there is negligible scope for area expansion, the growth rate of rice production must not only be sustained but even accelerated in order to meet the growing demand. Increasingly, water is becoming a single most constraint to produce more rice to meet increasing demand (Kunimitsu, 2006)[8].

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There is a crisis in rice production-both for the farmer, battling unprecedented changes in weather and escalating costs of cultivation, and the government, which needs to ramp up rice production by two million tonnes annually to ensure the nation's food security. In spite of providing assured irrigation, use of pest-resistant, high-yielding varieties, and high inputs of fertilizers and pesticides, rice yields in India are plateauing. With inevitable growth of demand for human and industrial needs, water available for agriculture will become scarcer in the future (Kunimitsu, 2006)[8]. India is a highly water-stressed country. Hence, India needs to invest in improving its water productivity, and any capacity to produce more rice with less water (Shobarani et al, 2010; Satyanarayana et al. 2007)[16][13]. This will guide to sustainable water and food security. Moreover, every kilogram of rice requires 3000-5000 liters of water, making it an ecologically unsound crop; there is a question mark over the issue of increasing rice production. More than 70 percent of the country's ground and surface water is being used for agriculture, and out of this, 70 percent is allocated to rice cultivation.

Recently a new approach, widely known as System of Rice Intensification (SRI), has attracted much attention in the agricultural scientific community as well as among some farmers because of its report (by some) success in increasing rice yield per unit area without investing more for its inputs (with the possible exception of labor). SRI was conceptualized by Henri de Laularié, a French missionary priest, in Madagascar in the early 1980s as a complementary suite of rice management techniques. The SRI is (seen by some as) one of the most promising agricultural innovations that are claimed to be both more sustainable and more productive than conventional rice cultivation (Satyanarayana et al. 2007; Kunimitsu, 2006)[13][8]. SRI is proposed as more accessible to small landholders (Stoop et al. 2002)[17] and more favorable for the environment than is conventional transplanting, with its continuous flooding and heavy reliance on inorganic fertilization and agrochemical crop protection (Uphoff 2003)[22].

It has been claimed that SRI can increase rice yield substantially (Kabir and Uphoff, 2007; Lin and Zhu 2011)[6] whereas some agricultural scientists noted that it reduced input requirements such as seeds and water. It has been claimed by its proponents that using SRI technology rice yield can be increased up to 15 to 20 tons ha^{-1} (Uphoff and Randriamiharisoa, 2002)[22]. The relative scarcity of studies based on farmers' plots in a variety of conditions raises the question of the replicability of higher yields due to SRI practices, as obtained from(at least some) controlled experiments, under different conditions and by ordinary farmers.

This paper addresses those lacunas in the existing literature. First, it focuses on soil dynamics as a possible mechanism linking SRI practices and higher yields. Our data set contains information on chemical and biological compositions in the soil under SRI and non-SRI practices. Secondly, we set up farmers' trials in 15 villages with resident farmers operating SRI practices (as well as conventional/non-SRI) practices on their own farms, with technical assistance from the research team. While the use of farmers' plots, rather than of experimental stations, possibly introduces data Errors that may compromise, to some extent, scientific rigor in establishing the relationship between soil dynamics and yields, we believe that the stability of our empirical findings across a relatively large number of farmers' plots among different villages could provide a high level of confidence in the potential replicability of our SRI results in the hands of ordinary farmers who is rarely found in the existing literature.

2. Materials and Methods

2.1 Study Site

Table 1. Name of village with their geographical position

Name of the Village	Latitude	Longitude
Alampur	22°23'09"	87°35'07"
Alidadpur	22°21'31"	87°30'59"
Amodpur	22°23'59"	87°31'06"
Balabhadrapur	22°30'29"	87°35'59"
Banasda	22°22'06"	87°37'00"
Brindabanpur	22°25'05"	87°33'11"
Chaltageriya	22°25'48"	87°32'53"
Dingal	22°20'58"	87°38'09"
Galimpur	22°21'39"	87°30'31"
Kazichak	22°24'22"	87°29'31"
Khasbazar	22°23'27"	87°37'51"
Madhabpur	22°23'17"	87°32'44"
Nandeswar	22°30'06"	87°35'33"
Naraharipur	22°24'23"	87°31'04"
Paikpari	22°24'06"	87°38'40"

2.2 Crop Management Condition

Those farmers were selected for the studies that were practicing SRI technology by themselves own their farms

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during the Boro cultivation season (January-April). The study was continued for three consecutive years 2012-14 on the same fields. Farmers were provided necessary inputs, including seeds and fertilizer (but no labor) by the research team. In addition, technical know-how of SRI cultivation was also provided through regular visits and/or personal communication by the research team. In addition to the SRI plots, a similar size of the non-SRI plot was maintained for conventional cultivation in comparison purposes. Farmers were provided a sheet to keep the record on input uses as well as production throughout the crop growing period. Soil samples from each plot were collected before the start of the experiment as well as after harvesting of the crop.

SRI is an acronym for System of Rice Intensification, a new technique to grow rice more efficiently using much less water. In SRI, 8-12-day seedlings instead of the normal three-four-week-old seedlings are transplanted at wider spacing (25 cm x 25 cm). Only one seedling is planted per hill. Water is used sparingly to keep the soil moist (alternate wetting and drying) but not continuously flooded. Five times weeding was carried out mechanically through a rotary weeder (small hand-driven machine) at 10-day intervals, but instead of throwing out the weeds these are pushed through the soil for aeration and providing organic matter. Use of farmyard manure is encouraged because SRI cultivation responds better to organic fertilizer than chemical fertilizers. Seedlings are raised in unflooded nurseries, not planted densely and have to be well supplied with organic matter. There is an option of direct-seeding, but transplanting is common. Two cm irrigation water was applied after hairline cracks appeared in the soil surface up to panicle initiation (PI); then after PI, irrigation was given 1 day-after the disappearance of pond water. Inter-cultivation was done five times with a rotary weeder at a 10-day intervals. The same recommended fertilizer was applied as with conventional practice.

In conventional practice 21-24-day-old seedlings with the above plant density; plots were irrigated to a 5 cm depth 1 day-after the disappearance of pond water; hand weeding was done three times; recommended fertilizers were applied: 120 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5, 60 kg ha^{-1} K_2O. The P was applied basally, while N was applied in four splits: 40% basal and 20% each at active tillering, panicle initiation and first flowering stages. The K was applied in three splits: 50% basal and 25% each at tillering and panicle initiation stages.

2.3 Soil Analysis

Soil samples from 0-20 cm depth were collected scientifically from each plot. These samples were air-dried under shed and sieved through 2 mm mesh sieve. Fresh soil samples were used for estimating of biological parameters, and results were expressed on the moisture-free basis. The moisture content was determined by the gravimetric method. Population densities of total bacteria and fungus were enumerated by using serial dilution plate technique. Data were log transformed and expressed as colony-forming units (CFU) log10 g^{-1} dry soil. Soil reaction, conductivity, organic carbon, available nitrogen, phosphorus and potassium are estimated by the standard methods advocated by Jackson, 1973.

Total plants in an area of 5 m× 5 m (25 m^2) for each replicate were harvested (excluding border rows) for determining of rice grain yield per unit area, and reported grain yield was adjusted to 14.5% seed moisture content. The Harvest Index was calculated by dividing the dry grain yield into the total weight of dry matter of aboveground parts. Plant height, effective tiller number, panicle length, grain weight, and dry matter were determined from the crop harvested from a representative square meter area from each replication.

4. Statistical Analysis

All the data were statistically analyzed using analysis of variance (ANOVA) as applied to a completely randomized block design (Gomez and Gomez 1984)[4]. The significance of the treatment effect was determined using F-Tests; and to determine the significance of the difference between the means of the treatments, least significant difference (LSD) was calculated at the 5% probability level.

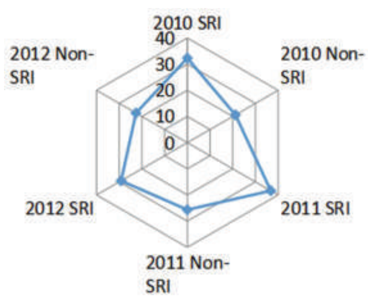

Figure 1. (a) Soil reaction (pH)

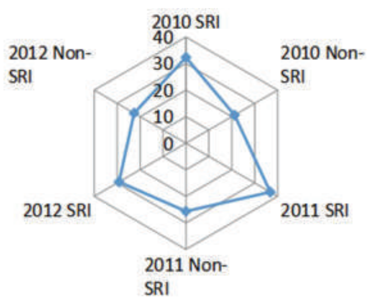

Figure 1. (b) Soil organic carbon (%)

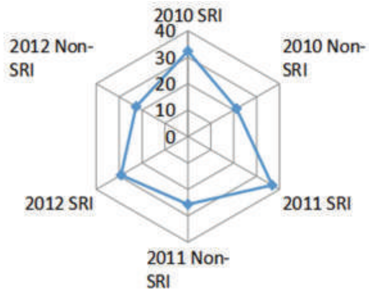

Figure 1. (c) Available Nitrogen (kg ha^{-1})

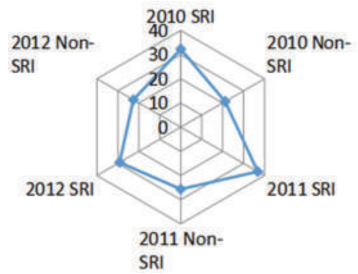

Figure 1. (d) Available Phosphorus (kg ha^{-1})

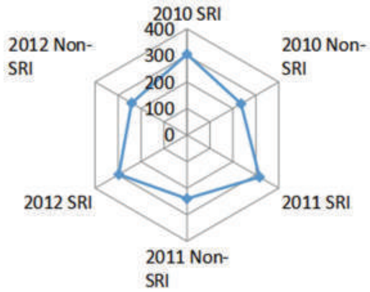

Figure 1. (e) Available Potassium (kg ha^{-1})

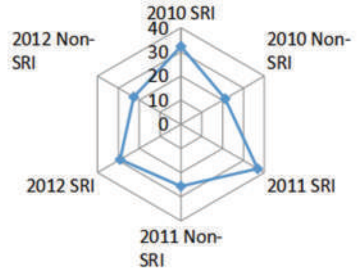

Figure 1. (f) Soil Fungal Population (CFU 10^{-4}/ml)

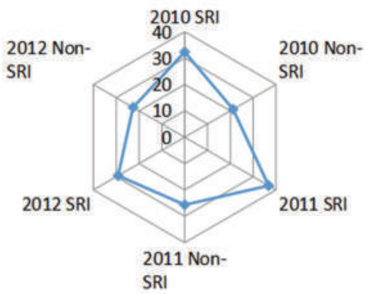

Figure 1. (g) Soil Bacterial Population (CFU 10^{-6}/ml)

Figure 1. Soil properties as influenced by SRI and Non-SRI practices

5. Results and Discussion

5.1 Rice growth and Yield Component

Rice growth and yield component such as plant height, number of tillers, panicle length and weight, number of seeds per panicle and test weight were recorded for three seasons. They were influenced remarkably under different crop management conditions (Table 2). Variation in the above parameters over the years was almost constant, but following the same trend. On an average, plant height increased by 12%, number of tillers per square meter by 85%, number of reproductive tillers per hill by 286%, weight of panicle per hill by 139%, number of seeds per panicle by 41% and test weight by 26% due to SRI practice over the non-SRI practice.

Tillering ability (panicle bearing tillers) in rice has a close relationship to the number of phyllochrons completed before entering the reproductive stage (Stoop et al. 2002; Thakur et al. 2009)[17][20]. In the SRI method of rice cultivation, individual plants with their more favorable growing conditions have shorter phyllochrons, which results in their having more productive tillers and larger root systems (Katayama 1951; Thakur et al. 2009)[20]. Rice plants grown under standing water encounter hypoxic (anoxic) soil conditions, and about three-fourths of their roots are degenerated by the flowering stage (Kar et al. 1974)[7]. Further, transplanting of young seedlings, as in SRI methods, has the tendency to improve their root characteristics such as root length, root density and root weight compared with older seedlings, as used in non-SRI (Mishra and Salokhe 2008)[9]. Other studies have also reported that SRI plants have deeper root systems and larger roots compared to those conventionally grown in flooded rice systems (Satyanarayana et al. 2007; Tao et al. 2002)[13][18]. Better root

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Table 2. Change in growth and yield parameters of rice as influenced by the crop management conditions

Parameter	2012			2013			2014			Mean		
	SRI	non-SRI	Percent Change	SRI	non-SRI	Percent Change	SRI	non-SRI	Per cent Change	SRI	non-SRI	Percent Change
Plant height (cm)	85.40	75.49	13.13	100.06	86.49	15.69	99.86	92.76	7.65	95.11	84.91	12.01
Number of tillers m^{-2}	1109.78	636.38	74.39	985.31	559.73	76.03	799.21	364.98	118.98	964.77	520.36	85.40
Number of tillers per hill	61.09	11.89	413.83	49.77	16.24	206.39	37.81	12.17	210.76	49.56	13.43	269.02
Reproductive tillers per hill	50.64	9.41	438.30	43.90	14.24	208.16	35.48	10.02	253.92	43.34	11.22	286.27
Panicle length (cm)	21.12	18.30	15.42	24.28	18.67	30.08	24.60	18.43	33.46	23.33	18.47	26.31
Panicle weight /hill	126.62	64.31	96.88	91.40	49.42	84.93	146.38	38.59	279.34	121.47	50.77	139.26
Seeds/ panicle	162.20	121.13	33.90	208.42	148.78	40.09	230.45	156.00	47.73	200.36	141.97	41.13
Grain weight (g)	23.64	18.60	27.12	24.83	19.82	25.29	21.71	17.11	26.91	23.39	18.51	26.36
Grain yield (kg/ha)	7148.13	3327.34	114.83	7219.37	5380.00	34.19	8619.79	5793.33	48.79	7662.43	4833.56	58.53
Straw yield (kg/ha)	13086	5524.19	136.89	8640.0	6311.02	36.90	12303	8153.28	50.90	11343	6662.83	70.24

development in the SRI system might have increased all growth and yield parameters (Randriamiharisoa & Uphoff, 2002)[11].

5.2 Rice Grain and Straw Yield

Rice grain and straw yield were significantly affected by soil conditions. In all three-year straw and grain yield was higher in SRI (Table 3). Average increment in straw and grain yield due to SRI over the non-SRI is 70% and 59% respectively. Plants grown in SRI had more open architecture, with the wide spread of tillers, covering more ground area, and more erect the leaves (data not shown), which avoided mutual shading of leaves (Seshu & Cady, 1984; Senthilkumar et al, 2008)[15][14]. With higher light interception, this would lead to more photosynthesis and higher grain yield in SRI compared to non-SRI. A number of previously published reports on SRI have shown enhancement in rice yield with these methods (Namara et al. 2008; Satyanarayana et al. 2007; Sato and Uphoff 2007; Thakur et al. 2009)[10][13][12][20]. The higher number of days taken to maturity in SRI practice was directly correlated to higher rice yield over the Non-SRI practice (Table 3).

5.3 Soil Reaction and Organic Carbon

SRI had a positive impact on soil reaction and organic matter content. Before starting the experiments, soil reaction of all the fields was acidic. The soil became more acidic in non-SRI practices, whereas some positive corrections were observed in SRI practices (Table 4 & 8 & Figure 1). Similarly, organic carbon was built up in SRI practices because of higher root volume and biomass (Carpenter-Boggs et al, 2000; Chapagain et al, 2010)[1][2].

5.4 Residual Soil Fertility

Residual soil fertility was measured in terms of available nitrogen, phosphorus (P) and potassium (K). SRI practices had a positive impact on residual soil fertility owing to higher microbial and biological activity guides to better soil fertility (Shobarani et al, 2010; Thakur et al, 2010; Thiyagarajan et al, 2002)[16][19][21]. However, reduction in soil fertility was observed in non-SRI practices (Table 5,6 & 8 & Figure 1).

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Table 3. Number of days taken to maturity by the rice varieties under different crop management condition

Name of village	Crop management condition	Variety			Days to maturity		
		2012	2013	2014	2012	2013	2014
Alampur	SRI	IET-4786	IET-1010	Shyamasri	91	111	98
	Non-SRI	IET-4786	IET-1010	Shyamasri	88	--	111
Alidadpur	SRI	Saru lalat	IET-4786	Saru lalat	100	99	97
	Non-SRI	Saru lalat	IET-4786	Saru lalat	86	88	112
Amodpur	SRI	IET-4786	IET-4786	IET-4786	87	110	98
	Non-SRI	IET-4786	IET-4786	IET-4786	61	115	98
Balabhadrapur	Non-SRI	IET-4786	IET-4786	IET-4786	49	94	94
	SRI	IET-4786	IET-4786	IET-4786	93	118	112
Bansda	SRI	Sankar	Sankar	Shyamasri	91	110	102
	Non-SRI	Sankar	Sankar	Shyamasri	83	85	110
Brindabanpur	SRI	Supar sankar	IET-1010	Shyamasri	68	122	105
	Non-SRI	Supar sankar	IET-1010	Shyamasri	110	108	110
Chaltagerya	SRI	IET-4786	IET-4786	5152	92	101	112
	Non-SRI	IET-4786	IET-4786	5152	83	83	109
Dingal	SRI	IET-4786	IET-4786	IET-4786	84	84	85
	Non-SRI	IET-4786	IET-4786	IET-4786	97	107	106
Galimpur	SRI	IET-4786	IET-4786	Natia	96	102	109
	Non-SRI	IET-4786	IET-4786	Natia	87	89	92
Kazi Chak	SRI	IET-1010	Ananya	Ananya	86	81	89
	Non-SRI	IET-1010	Ananya	Ananya	72	117	94
Khasbazar	SRI	IET-4786	IET-4786	IET-4786	104	113	88
	Non-SRI	IET-4786	IET-4786	IET-4786	44	123	111
Madhabpur	SRI	IET-4786	IET-4786	IET-4786	96	95	101
	Non-SRI	IET-4786	IET-4786	IET-4786	85	88	96
Nandeswar	SRI	IET-4786	IET-4786	IET-4786	95	120	113
	Non-SRI	IET-4786	IET-4786	IET-4786	71	96	91
Naraharipur	SRI	IET-4786	IET-4786	IET-4786	79	112	106
	Non-SRI	IET-4786	IET-4786	IET-4786	--	113	91
Paiakpari	SRI	IET-4786	IET-4786	IET-4786	105	112	105
	Non-SRI	IET-4786	IET-4786	IET-4786	79	100	94

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Table 4. Soil reaction and organic carbon as influenced by the crop management conditions

Name of villages	Soil reaction								Soil organic carbon (%)							
	2012		2013		2014		Mean		2012		2013		2014		Mean	
	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI
Alampur	6.35	6.71	6.36	6.63	6.45	6.73	6.39	6.69	0.97	1.19	1.01	1.01	0.92	0.98	0.97	1.06
Alidadpur	6.42	6.88	6.11	6.91	5.93	6.95	6.15	6.91	1.01	1.31	1.01	1.29	0.99	1.21	1.00	1.27
Amodpur	6.40	6.55	6.48	6.71	6.38	6.69	6.42	6.65	1.01	1.37	1.12	1.23	0.98	1.24	1.04	1.28
Balabhadrapur	6.02	6.45	6.02	6.95	6.12	6.68	6.05	6.69	1.01	1.12	0.9	1.03	0.88	1.19	0.93	1.11
Bansda	5.75	6.52	5.97	6.12	5.9	6.84	5.87	6.49	0.79	0.95	0.76	0.86	0.79	0.91	0.78	0.91
Brindabanpur	5.65	6.59	5.81	6.72	5.62	6.82	5.69	6.71	1.18	1.47	0.94	1.51	1.01	1.43	1.04	1.47
Chaltageriya	5.21	5.73	5.55	5.98	5.94	6.02	5.57	5.91	0.98	1.23	0.96	1.19	0.94	1.11	0.96	1.18
Dingal	6.69	6.78	6.72	7.08	6.75	7.03	6.72	6.96	0.91	0.98	0.86	0.99	0.87	1.01	0.88	0.99
Galimpur	5.50	6.18	5.81	5.98	5.32	6.01	5.54	6.06	0.91	0.91	0.71	0.89	0.84	0.88	0.82	0.89
Kajichak	5.35	5.75	5.64	5.97	5.54	6.03	5.51	5.92	0.97	0.98	0.87	1.06	0.84	1.02	0.89	1.02
Khasbazar	4.75	6.55	4.94	6.32	5.59	6.64	5.09	6.50	0.98	1.04	0.89	1.06	0.91	0.99	0.93	1.03
Madhabpur	5.75	6.75	5.84	6.9	5.54	6.72	5.71	6.79	0.95	1.10	0.94	1.26	0.89	1.32	0.93	1.23
Nandeswar	5.40	6.35	5.89	6.51	5.82	6.34	5.70	6.40	0.79	0.98	0.87	0.95	0.82	1.01	0.83	0.98
Naraharipur	6.51	7.01	6.74	7.12	6.84	7.24	6.70	7.12	0.89	1.16	0.96	0.97	0.9	1.09	0.92	1.07
Paikpari	6.50	6.71	6.78	6.64	6.68	6.76	6.65	6.70	0.93	0.88	0.89	0.95	0.87	0.91	0.90	0.91
Mean	5.88	6.50	6.04	6.57	6.03	6.63	5.99	6.57	0.95	1.11	0.91	1.08	0.90	1.09	0.92	1.09
SEm(+/-)	0.020		0.019		0.018		0.017		0.006		0.007		0.006		0.005	
CD (0.05%)	0.043		0.040		0.038		0.036		0.012		0.014		0.012		0.010	

Table 5(a). Available nitrogen and phosphorus as influenced by the crop management conditions

Name of villages	Available Nitrogen (kg ha^{-1})							
	2012		2013		2014		Mean	
	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI
Alampur	251.11	278.75	278.51	294.78	306.07	316.98	278.56	296.84
Alidadpur	250.21	275.97	266.9	285.16	280.99	316.11	266.03	292.41
Amodpur	200.7	246.38	188.51	269.69	210.74	263.42	199.98	259.83
Balabhadrapur	197.25	225.79	136.87	196.32	316.11	386.36	216.74	269.49
Bansda	207.98	266.61	328.33	343.42	280.99	316.11	272.43	308.71
Brindabanpur	267.39	318.34	244.92	301.05	245.86	333.67	252.72	317.69
Chaltageriya	300.76	327.74	267.98	308.41	351.23	386.36	306.66	340.84
Dingal	268.93	281.47	316.78	343.5	289.34	323.48	291.68	316.15
Galimpur	216.38	235.2	218.15	256.97	263.42	280.99	232.65	257.72
Kajichak	201.83	241.47	200.52	284.6	234.76	258.78	212.37	261.62
Khasbazar	319.87	322.83	257.85	325.13	263.42	298.55	280.38	315.50
Madhabpur	284.8	297.92	225.79	296.97	280.99	316.11	263.86	303.67
Nandeswar	201.25	227.42	225.79	275.26	298.55	386.36	241.86	296.35
Naraharipur	294.43	301.66	281.88	294.43	368.79	333.67	315.03	309.92
Paikpari	144.26	172.48	184.23	206.14	280.99	351.23	203.16	243.28
Mean	240.48	268.00	241.53	285.46	284.82	324.55	255.61	292.67
SEm(+/-)	0.758		1.180		1.489		0.852	
CD (0.05%)	1.551		2.447		3.088		1.767	

Table 5(b). Available phosphorus as influenced by the crop management conditions

Name of villages	Available Phosphorus (kg ha^{-1})							
	2012		2013		2014		Mean	
	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI
Alampur	49.18	73.92	61.18	90.89	59.35	62.27	56.57	75.69
Alidadpur	62.84	72.19	55.35	80.25	79.84	83.3	66.01	78.58
Amodpur	60.27	87.46	60.15	95.65	70.72	91.28	63.71	91.46
Balabhadrapur	51.39	66.43	67.53	74.54	60.34	75.8	59.75	72.26
Bansda	41.83	62.08	47.26	66.2	50.21	55.69	46.43	61.32
Brindabanpur	59.00	81.47	84.85	97.55	65.38	80.25	69.74	86.42
Chaltageriya	64.57	69.86	66.45	88.22	70.35	82.41	67.12	80.16
Dingal	70.10	80.10	80.76	94.22	73.32	86.97	74.73	87.10
Galimpur	56.64	65.28	73.94	87.41	82.47	93.41	71.02	82.03
Kajichak	47.28	72.31	58.3	92.82	53.65	87.89	53.08	84.34
Khasbazar	65.23	99.03	73.78	89.71	80.15	95.39	73.05	94.71
Madhabpur	51.20	57.77	47.65	63.10	51.47	72.53	50.11	64.47
Nandeswar	38.25	46.96	52.26	61.37	43.60	56.55	44.70	54.96
Naraharipur	12.22	35.93	16.34	45.82	60.49	80.25	29.68	54.00
Paikpari	66.25	74.57	71.1	81.18	60.38	75.3	65.91	77.02
Mean	53.08	69.69	61.13	80.60	64.11	78.62	59.44	76.30
SEm(+/-)	0.430		0.044		0.369		0.309	
CD (0.05%)	0.892		0.913		0.765		0.642	

Table 6. Residual soil available potassium as influenced by the crop management conditions

Name of villages	Available Potassium (kg ha-1)							
	2012		2013		2014		Mean	
	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI
Alampur	180.32	267.52	168.80	248.95	240.50	279.25	196.54	265.24
Alidadpur	214.27	242.24	208.15	289.70	120.15	163.55	180.86	231.83
Amodpur	181.12	280.56	188.15	317.20	162.10	166.10	177.12	254.62
Balabhadrapur	256.21	313.60	219.50	296.00	196.85	300.40	224.19	303.33
Bansda	363.68	461.44	323.70	452.50	279.25	393.95	322.21	435.96
Brindabanpur	289.48	354.80	222.90	267.68	226.80	278.45	246.39	300.31
Chaltageriya	205.36	216.44	235.62	301.34	292.05	304.45	244.34	274.08
Dingal	165.44	174.48	180.25	231.67	173.67	225.54	173.12	210.56
Galimpur	234.92	270.40	255.30	283.50	209.80	251.50	233.34	268.47
Kajichak	141.20	213.92	134.10	284.00	154.87	243.45	143.39	247.12
Khasbazar	413.28	576.00	416.80	536.20	454.85	478.00	428.31	530.07
Madhabpur	171.75	235.84	264.50	304.65	291.50	328.00	242.58	289.50
Nandeswar	220.12	293.28	263.58	318.50	250.65	353.00	244.78	321.59
Naraharipur	297.60	359.44	280.00	322.90	297.85	382.50	291.82	354.95
Paikpari	201.20	313.92	234.10	284.20	264.15	301.00	233.15	299.71
Mean	235.73	304.93	239.70	315.93	241.00	296.61	238.81	305.82
SEm(+/-)	1.902		1.802		1.636		1.210	
CD (0.05%)	3.945		3.738		3.393		2.510	

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Table 7. Microbial populations as influenced by the crop management conditions

Name of villages	Soil Fungal Population (Colony Forming Units 10^{-4}/ml)								Soil Bacterial Population (Colony Forming Units 10^{-6}/ml)							
	2012		2013		2014		Mean		2012		2013		2014		Mean	
	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI	SRI
Alampur	12.02	15.68	13.90	14.90	27.50	41.00	17.81	23.86	56.52	82.40	25.60	41.30	30.40	33.80	37.51	52.50
Alidadpur	12.10	14.32	13.20	14.60	10.70	12.00	12.00	13.64	16.40	36.20	22.20	27.30	18.50	20.80	19.03	28.10
Amodpur	11.48	14.85	13.80	10.20	9.90	11.00	11.73	12.02	12.52	13.90	32.60	48.60	15.60	26.00	20.24	29.50
Balabhadrapur	12.60	16.00	15.20	16.70	12.30	15.10	13.37	15.93	14.70	20.00	17.50	32.80	27.20	36.30	19.80	29.70
Bansda	10.27	15.41	11.10	12.50	21.00	25.00	14.12	17.64	24.15	50.20	24.10	48.12	25.50	32.00	24.58	43.44
Brindabanpur	11.20	18.40	12.20	16.90	16.50	17.20	13.30	17.50	6.27	15.20	18.90	24.81	10.10	15.60	11.76	18.54
Chaltageriya	12.20	10.85	13.75	11.10	12.20	12.50	12.72	11.48	6.50	13.80	15.50	16.50	18.00	19.20	13.33	16.50
Dingal	14.25	17.34	13.60	19.20	12.98	18.34	13.61	18.29	25.80	38.82	12.40	28.00	19.76	32.48	19.32	33.10
Galimpur	12.50	16.20	13.50	16.20	11.85	12.00	12.62	14.80	59.20	72.80	69.50	81.20	13.00	25.00	47.23	59.67
Kajichak	13.97	14.39	14.20	15.80	14.87	16.87	14.35	15.69	14.30	25.20	28.50	36.30	21.45	30.67	21.42	30.72
Khasbazar	10.55	15.08	12.20	15.00	14.30	14.70	12.35	14.93	19.60	29.10	35.50	41.20	28.70	34.10	27.93	34.80
Madhabpur	13.20	11.80	11.80	12.60	10.60	11.50	11.87	11.97	21.20	23.40	27.50	48.30	30.80	42.00	26.50	37.90
Nandeswar	12.10	11.60	12.50	14.00	13.40	18.90	12.67	14.83	16.20	32.50	29.90	32.80	35.90	40.06	27.33	35.12
Naraharipur	13.13	13.48	14.30	13.90	11.00	12.00	12.81	13.13	11.95	14.02	11.65	28.10	17.50	19.00	13.70	20.37
Paikpari	12.00	13.46	12.50	15.10	12.40	18.90	12.30	15.82	12.76	17.10	13.40	16.30	26.90	30.60	17.69	21.33
Mean	12.24	14.59	13.18	14.58	14.10	17.13	13.17	15.43	21.20	32.31	25.65	36.78	22.62	29.17	23.16	32.75
SEm(+/-)	0.117		0.112		0.168		0.092		0.380		0.336		0.185		0.198	
CD (0.05%)	0.243		0.232		0.349		0.190		0.789		0.697		0.384		0.412	

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5.5 Soil Microbial Population

Microbial population measured in terms of fungal and bacterial plate count was significantly influenced by the rice management condition. Microbial population was consistently higher in the SRI system (Table 7 & 8& Figure 1). Quantification of microbial population through plate-count techniques estimates probably less than 10% of the total microflora in the soil. Therefore, molecular quantification (a more reliable method) needs to be done in future studies. The presence of more microbial and biological activity leads to beneficial functions for crops such as plant growth promotion, nitrogen fixation, phosphate solubilization, induced systemic resistance, and protection against pathogens (Carpenter-Boggs et al, 2000)[1]

Table 8. Change in soil properties as influenced by the crop management conditions

Parameter	2012		2013		2014	
	non-SRI	SRI	non-SRI	SRI	non-SRI	SRI
pH	(0.09)	0.16	(0.11)	0.08	(0.14)	0.10
Organic carbon (%)	(0.07)	0.12	(0.08)	0.10	(0.08)	0.12
Available Nitrogen (kg ha^{-1})	(18.52)	21.84	(14.29)	28.19	(12.49)	19.28
Available Phosphorus (kg ha^{-1})	(4.17)	7.98	(4.30)	3.89	(3.43)	5.98
Available Potassium (kg ha^{-1})	(37.85)	35.38	(23.40)	23.08	(34.20)	28.13
Soil Fungal Population (Colony Forming Units 10^{-4}/ml)	(1.37)	2.20	0.26	1.61	(0.34)	1.96
Soil Bacterial Population (Colony Forming Units 10^{-6}/ml)	(2.13)	15.65	(1.20)	15.67	(1.79)	16.86

*Figures in parenthesis are negative

6. Conclusions

During the present three-year investigation, fifteen farmers were selected those were practicing SRI technology. On an average, the study noted that plant height increased by 12%, number of tillers per square meter by 85%, number of reproductive tillers per hill by 286%, weight of panicle per hill by 139%, number of seeds per panicle by 41% and test weight by 26% due to SRI practice over the non-SRI practice. Average increment in straw and grain yield due to SRI over the non-SRI is 70% and 59% respectively. The physico-chemical and biological properties of the soil improved due to SRI practice. The water saved for rice can be effectively used for increasing the area under rice or for other irrigated dry crops in the cropping sequence, thereby, enhancing the rice productivity.

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