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Impacts of rice intensification system on two C. D. blocks of Barddhaman district, West Bengal

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Rice is an important cereal crop of West Bengal and in many of the Indian states. There is a compelling need to increase rice productivity vertically in West Bengal due to less availability of land and greater dependency of the population on the productivity of the land. For this reason, the economic and ecological potentiality of the system of rice intensification (SRI) has been evaluated by several researchers. In the present study, Monteswar and Memari-II C. D. blocks of Barddhaman district, West Bengal have been selected to analyse the impacts of SRI on economic and ecological aspects of rice-growing. Results show that benefit–cost (B : C) ratio in SRI practice is significantly higher than the conventional method of rice cultivation. Under SRI B : C ratio varies from 5.06 : 1 to 3 : 1, but in the conventional method it varies from 2.18 : 1 to 1.78 : 1. Therefore, SRI farmers are experiencing multiple benefits in terms of both economics and ecology.

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WATER shortage appears to be one of the major limitations affecting rice production[1]. The Food and Agriculture Organization (FAO) of the United Nations estimates that rice crop consumes about 4000–5000 litres of water/kg of grain produced. Since water for rice production has become increasingly deficit, water saving sustaining the high productivity has become a priority in rice research[2].

The system of rice intensification (SRI) was developed in 1980s in Madagascar[3], as a water-saving practice with many-fold increase in crop yield[4]. This method is also ecologically beneficial and is applicable for wheat, sugarcane and several other crops. Also it is more suitable for the small farmers because they can manage their land using this method by their own innovation[5].

Analysing the potentiality of SRI remains a continuing concern among many researchers[6–16] due to an agro-ecologically imbalanced condition in paddy fields. Pandey[17] has studied the relation of different weed control methods with different variables of rice cultivation under SRI in an experimental field in Nepal and found that three mechanical weeding methods under SRI gave the best result with respect to the number of effective tillers/sq. m, grain number, grain weight, yield/ha and benefit–cost (B : C) ratio. Rajitha and Reddy[18] have found that SRI with integrated nutrient management (50% Farm Yard Manure (FYM) + 50% RD of NPK) and SRI with 100% organic manuring saved 28.63% and 34.25% input cost respectively, compared to conventional method of transplanting with recommended fertilizer and cultural practices.

The key elements of SRI practice are discussed below. Young seedlings (not more than 15 days, preferably 8–12 days) are transplanted in SRI practice to achieve the potential of getting higher yield. Transplantation is done by careful removing of the seedlings from the nursery bed and putting them vertically at a shallow depth (1–2 cm) in the soil within 15 min of their removal from the nursery bed. Careful handling of seedlings avoids trauma to the roots, with little or no interruption of plant growth and no transplant shock. Also, transplantation should be done in a square pattern of at least 25 × 25 cm distance between rows and hills in order to give the roots of a single plant enough space to collect nutrients from the soil (Figure 1).

Intermittent irrigation with cycle ranging from 6 to 14 days should be done to maintain alternative dry and wet conditions in paddy field (Figure 2). This avoids the suffocation and degeneration of rice plant roots and also supports more abundant and diverse populations of aerobic soil organisms that provide multiple benefits to the plants. It also ensures optimum supply of water and oxygen, which results in larger and deeper root growth, thus giving the rice plants more resilience to adverse climatic conditions, such as droughts, storms or extreme temperatures.

Non-flooded condition of the field promotes soil aeration. Beside this, SRI recognizes frequent use of mechanical weeder. Non-flooded condition creates weed problem and so use of mechanical weeder aerates the soil and ensures decomposition of the weed, which in turn supplies nutrients to the plants. Success of SRI basically depends on this practice.

SRI practices give better results to the extent that the soil is well-supplied with organic matter. When organic matter is added, the microorganisms in the soil multiply manifold and bring nutrients into available form. Thus nutrients are made available as and when they are needed.

The present work is based mainly on field study. Results are on the basis of direct field observations. Fifteen plots under SRI practice in each of Monteswar and Memari-II the C. D. blocks were selected randomly for the study. All of them have adopted the direct seeding method for which there is no need to prepare the nursery bed. Drum seeder is used for direct seeding and spacing of the plants 25 cm apart and 24 cm between two plants in a row. All the farmers used 10 tonnes of organic manure per hectare and very low quantity of chemical fertilizer. Intermittent irrigation was followed to maintain the alternative dry and wet conditions. Farmers have followed chemical, mechanical and manual method of weeding according to their own choice.

Information was collected regarding the existing method (conventional) of rice cultivation. Finally, the two practices were tested at 95% significant level. As the sample size is 30 (which falls under the category of large sample size), 'approximate test' using normal distribution has been selected. The hypotheses have been tested using the following formula

$$Z = (p - p_0)/\text{SE of } p,$$

where p and p_0 are the proportions of samples from population, and SE is the standard error of estimate[19].

Initially, data are collected for *kharif* season in 2013. But in *kharif* season due to monsoon rainfall no expenditure was required for water.

Economically, SRI practice is highly profitable and helps farmers to get a considerable return with relatively low amount of investment[12,16]. Seed requirement in SRI is 6–10 kg/ha whereas in the traditional method it is 30–40 kg/ha. The cost of labour for transplantation of seedling is very low as the concerned farmers have adopted the process of direct seeding using a drum seeder with the help of which a single labourer can seed 1 ha. But in the existing conventional method at least 55 labourers are needed for seedling transplantation in 1 ha. In addition, less expenditure in chemical fertilizers, pesticides and insecticides makes the total cost of cultivation relatively lower (Table 1).

Figure 1. Transplantation of seedlings in square pattern, Memari-II C. D. block.

Figure 2. Intermittent irrigation, Memari-II C. D. block.

Table 1. Comparative study of different variables of rice cultivation in the system of rice intensification and conventional method, Manteswar and Memari-II C. D. blocks, Barddhaman district, West Bengal

	System of rice intensification								Conventional method					
Plot no.	Total expenditure per hectare (Rs)	Productivity per hectare (kg)	Productivity per hectare (Rs)	Profit per hectare (Rs)	Benefit–cost (B : C) ratio	Fertilizer consumption per hectare (Rs)	Expenditure in mechanical manual weed control (Rs)	Expenditure in chemical–manual weed control (Rs)	Total expenditure per hectare (Rs)	Productivity per hectare (kg)	Productivity per hectare (Rs)	Profit per hectare (Rs)	B : C ratio	Fertilizer consumption per hectare (Rs)
1	27,501	7,416	111,240	83,739	4.04 : 1	4,944		27,501	38,872.2	4,944	74,160	35,287.8	1.91 : 1	5,562
2	25,523.4	7,663	114,945	89,421.6	4.50 : 1	2,719.2		25,523.4	40,170	5,191	77,865	37,695	1.94 : 1	4,635
3	22,495.2	7,581	113,715	91,219.8	5.06 : 1	3,090		22,495.2	39,861	5,191	77,865	38,004	1.95 : 1	4,913.1
4	40,788	8,405	126,075	85,287	3.09 : 1	3,090	40,788		43,260	5,686	85,290	42,030	1.97 : 1	4,944
5	33,681	6,922	103,830	70,149	3.08 : 1	3,151.8		33,681	37,698	4,944	74,160	36,462	1.97 : 1	519.12
6	25,956	6,674	100,110	74,154	3.86 : 1	3,201.24		25,956	37,049.1	4,944	74,160	37,110.9	2 : 1	4,882.2
7	29,046	7,169	107,535	78,489	3.70 : 1	3,028.2		29,046	37,080	4,944	74,160	37,080	2 : 1	5,283.9
8	24,720	6,922	103,830	79,110	4.20 : 1	2,842.8		24,720	37,080	4,944	74,160	37,080	2 : 1	4,913.1
9	26,574	6,839	102,585	76,011	3.86 : 1	4,017		26,574	39,768.3	4,697	70,455	30,686.7	1.77 : 1	4,789.5
10	30,900	6,427	96,405	65,505	3.12 : 1	3,399		30,900	42,024	5,686	85,290	43,266	2.03 : 1	4,974.9
11	31,827	6,674	100,110	68,283	3.15 : 1	3,708		31,827	41,406	5,438	81,570	40,164	1.97 : 1	5,160.3
12	37,698	8,322	124,830	87,132	3.31 : 1	2,595.6	37,698		39,212.1	5,686	85,290	46,077.9	2.18 : 1	4,727.7
13	23,484	6,427	96,405	72,921	4.11 : 1	3,028.2		23,484	36,462	4,944	74,160	37,698	2.03 : 1	4,696.8
14	28,397.1	6,716	100,740	72,342.9	3.55 : 1	2,966.4		28,397.1	39,861	5,191	77,865	38,004	1.95 : 1	4,789.5
15	24,102	6,592	98,880	74,778	4.10 : 1	3,337.2		24,102	37,389	4,944	74,160	36,771	1.98 : 1	4,913.1
16	25,956	6,674	100,110	74,154	3.86 : 1	3,151.8		25,956	39,552	4,697	70,455	30,903	1.78 : 1	5,005.8
17	34,453.5	8,281	124,215	89,761.5	3.61 : 1	3,182.7	34,454.5		40,077.3	5,315	79,725	39,647.7	1.99 : 1	5,160.3
18	28,551.6	6,922	103,830	75,278.4	3.64 : 1	2,935.5		28,551.6	39,700.32	5,191	77,865	38,164.68	1.96 : 1	4,264.2
19	24,689.1	6,633	99,495	74,805.9	4.03 : 1	2,842.8		24,689.1	37,698	4,944	74,160	36,462	1.97 : 1	4,480.5
20	38,470.5	8,281	124,215	85,744.5	3.23 : 1	2,811.9	38,470.5		40,788	4,944	74,160	33,372	1.82 : 1	4,356.9
21	31,641.6	7,540	113,100	81,458.4	3.57 : 1	3,090		31,641.6	41,189.7	4,944	74,160	32,970.3	1.80 : 1	5,129.4
22	27,593.7	7,292	109,380	81,786.3	3.96 : 1	3,090		27,593.7	36,431.1	4,450	66,750	30,318.9	1.83 : 1	4,171.5
23	23,916.6	6,551	98,265	74,348.4	4.11 : 1	2,935.5		23,916.6	37,080	4,697	70,455	33,375	1.90 : 1	4,233.3
24	28,774.08	6,922	103,830	75,055.92	3.61 : 1	2,997.3		28,774.08	38,532.3	5,438	81,570	43,037.7	2.12 : 1	4,326
25	29,528.04	6,798	101,970	72,441.96	3.45 : 1	3,120.9		29,528.04	39,552	5,562	83,430	43,878	2.11 : 1	4,635
26	33,372	8,158	122,370	88,998	3.67 : 1	3,275.4	33,372		39,552	4,944	74,160	34,608	1.88 : 1	4,696.8
27	29,046	7,045	105,675	76,629	3.64 : 1	3,238.32		29,046	37,698	4,944	74,160	36,462	1.97 : 1	5,098.5
28	34,855.2	8,281	124,215	89,359.8	3.56 : 1	2,657.4	34,855.2		39,737.4	5,068	76,020	36,282.6	1.91 : 1	3,708
29	33,922.02	8,281	124,215	90,292.98	3.66 : 1	3,738.9	33,922.02		38,316	4,944	74,160	35,844	1.94 : 1	4,882.2
30	24,102	6,427	96,405	72,303	3 : 1	2,873.7		24,102	37,018.2	5,068	76,020	39,001.8	2.05 : 1	4,326

Source: Field survey, 2013–14; computed by the authors.

The total expenditure in adopting SRI is less than the traditional method of rice cultivation. This can be symbolically written as

H_0: $\mu_1 = \mu_2$, against alternative, i.e., H_1: $\mu_1 < \mu$, and

$$z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}},$$

where H_0 is null hypothesis and H_1 the alternative hypothesis, $\overline{X}$ the mean, S the standard deviation and n is the sample size. (The same statistics has been applied in all other cases.)

Since the calculated value of $|z| = 10.44$ in this case is greater than the critical value of 1.64 at 5% level of significance, the null hypothesis is rejected (Table 2). Hence, it is inferred that there is a significant difference in total expenditure between the SRI method and the existing method of rice cultivation; it is less in the former compared to the latter.

Thus, SRI practice is affordable to the small farmers also. They can produce more rice using few seeds. Farmers do not require modern technological inputs[5]. Based on their experience farmers can innovate to make their practice more developed; make good compost on their own; follow organic SRI without the use of chemical fertilizers; use home-made pesticides and insecticides and thus reduce the total expenditure without affecting the resulting higher productivity.

The average productivity under SRI is 7227 kg/ha, whereas in conventional method it is 5084 kg/ha. Thus SRI introduces 40% increase in rice productivity compared to the existing conventional method (Table 1).

Since the calculated value of $|z| = 15.72$ in this case is greater than the critical value of 1.64 at 5% level of significance, the null hypothesis is rejected (Table 3). Hence, it is inferred that there is a significant difference in productivity per hectare between SRI method and existing method of paddy cultivation; it is more in the former than in the latter.

Optimum use of soil productivity become possible in SRI practice when some techniques are used in the paddy field understanding the psychology of the paddy plant. Use of organic fertilizers ensures activities of microorganisms in the soil; planting of single seedling at a regular spacing of 25 × 24 cm allows all plants enough space to collect nutrients from soil[12]; intermittent irrigation helps the roots of the paddy plant to grow deeply and increase the tolerance limit of the plants against storms[8,15]. All these simple techniques collectively contribute to higher productivity of SRI than conventional method. Productivity per hectare (in rupees) has been calculated taking the average market price of Rs 15/kg for the year of 2013–14 (Table 1).

Profit has been calculated by subtracting the total expenditure from total productivity (in rupees). As SRI practice records less expenditure and more productivity than conventional method, farmers get more profit in SRI practice. Farmers of the study area get a profit of Rs 79,032/ha in SRI practice, whereas it is Rs 37,258/ha in conventional method (Table 1).

Since the calculated value of $|z| = 27.41$ in this case is greater than the critical value of 1.64 at 5% level of significance, the null hypothesis is rejected (Table 4). Hence, it is inferred that there is a significant difference in profit (Rs) per hectare between the SRI method and the existing method of rice cultivation; it is more in the farmer than in the latter.

The B : C ratio is calculated using the following formula[6]

Benefit–cost ratio = Gross return/cost of cultivation.

The B : C ratio in SRI practice is found to be significantly higher than conventional method (Table 1).

In SRI, B : C ratio varies from 5.06 : 1 to 3 : 1, but in conventional method it varies from 2.18 : 1 to 1.78 : 1. In SRI practice very low transplantation cost due to use of drum seeder and a healthy agro-ecological environment result in higher productivity, higher profit per unit investment relatively compared to the conventional practice.

Let us now consider SRI from an ecological perspective. In SRI practice all the plots at first treated with good compost (30–60 tonnes/ha). Farmers do use chemical fertilizers, but the proportion of chemical fertilizers used per

Table 2. Test of significance (z test)

Particulars	SRI	Conventional method
Mean (Rs)	29,385.488	39,003.83
Standard deviation (Rs)	4,735.64867	1,740.84
Sample size	30	30
z test	–10.44	

Table 3. Test of significance for productivity estimation

Particulars	SRI	Conventional method
Mean (Rs)	7,227.833333	5,084.133333
Standard deviation (Rs)	679.8883825	309.1735071
Sample size	30	30
z test	15.72	

Table 4. Test of significance for profit estimation

Particulars	SRI	Existing technique
Mean (Rs)	79,032.012	37,258.166
Standard deviation (Rs)	7,401.380374	3,849.604601
Sample size	30	30
z test	27.41	

Table 5. Test of significance for consumption of fertilizer

Particulars	SRI	Conventional method
Mean (Rs)	3,168.692	4,605.954
Standard deviation (Rs)	456.7896216	863.804798
Sample size	30	30
z test	−8.06	

hectare is much less than that of traditional existing practices (Table 1).

Since the calculated value of $|z| = 8.06$ in this case is greater than the critical value of 1.64 at 5% level of significance, the null hypothesis is rejected (Table 5). Hence it is inferred that there is a significant difference in consumption of chemical fertilizers between the SRI method and the existing method of rice cultivation; it is less in the former than in the latter. The most important benefit of this practice is that it helps maintain the natural health of the soil, making it sustainable for a long time.

Weed growth in paddy fields under SRI practice is the result of intermittent irrigation and this makes the cultivation system problematic. Therefore, suitable sustainable method of weeding is required in this practice[10]. In the study area, the farmers use two methods of weeding. One is chemical–manual weed control method, where first chemical weeder is sprayed for weeding and then weeding is done manually the second and third time. The other weeding method is mechanical–manual weed control method, where a simple manually driven instrument called cono weeder is used three times in the paddy field. The first method reduces the expenditure for weeding, but use of chemical weeder has a negative impact on the organisms living in the soil due to which soil health is affected and thus the productivity as well. The second method of weeding makes the soil aerated, increases the availability of oxygen to plant roots and organisms living in the soil, which is good for plant health[17]. This condition helps boost the productivity as well.

In chemical–manual weed control method, farmers get threshold productivity of 6506.7 kg/ha whereas in the mechanical–manual weed control method, the threshold productivity is 7525.6 kg/ha. In the first method the value of slope is 0.0146, which indicates productivity of 0.0146 kg when the expenditure is one rupee, but in the second method the slope is 0.021 kg, which is higher than the first method of weeding.

As SRI practice is dynamic, more applied research is required for the highest output of potentiality of rice cultivation using this method. Irregularity of climatic condition due to climate change, uncertainty of rainfall, shortage of groundwater, lower sustainability of soil health and costly chemical fertilizers, are a challenge towards agricultural sustainability. On the other hand, the increasing population is creating more demand for crops to sustain its life and livelihood. Therefore, resilience building is necessary to combat the challenging situation from every sector of ecology, climate, economy and demography.

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