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DETERMINANTS OF SYSTEM OF ROOT INTENSIFICATION (SRI) METHOD, IN BIHAR STATE, INDIA

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Abstract: *Input-dependent strategies of 'modern agriculture' is less cost-effective and less sustainable, the benefits of system of root intensification (SRI) are considerable, especially in terms of resource conservation, production and addressing the challenges of climate change. Despite policy support that has been extended by nongovernmental organisations and some Governments, still the adoption of SRI has been restricted to some vicinity in India. This article is an attempt to explain principles, practices of SRI and reasons for the low adoption of SRI by farmers in Bihar and make policy suggestions, so that the discussion could be used for further research and policy support. The contents have been accumulated from literature and field visits and interaction with farmers in Bihar, state of India. This study finds that preference for SRI is higher among experienced farmers than younger farmers in Bihar. The analysis finds significant the role of literacy/theawareness programme in promoting farmers to use SRI in agriculture, in Bihar. Productivity of wheat and paddy has increased forty to sixty percentages, after using SRI practices. Limitations reported by the farmers are lack of awareness, labour intensive nature of SRI, shortage of skilled labour and absence of proper machines, useful for different types of soil. The findings of this study support that supply-side factors are playing major role in the adoption of SRI practise in Bihar. The adoption of SRI is still low in Bihar, because of the low role of demand side factors, Involvement of civil society with incentives may promote SRI practices in Bihar.*

Keywords: *Agriculture Development, Bihar, Paddy, SRI, Wheat.*

Introduction

Being mainly an agrarian economy, largely dependent on the vagaries of monsoon, the policy support to the farmers are essential in Bihar State, in India. Policies devoted to agriculture development have supported in a considerable amount the improvement of agriculture in Bihar, during recent years. Still, there are huge unused potential in agriculture in Bihar, in terms of productivity and crop diversification. Data shows that

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the average yield of paddy and wheat is lower than its production potential. Even though the State is rich in terms of availability of soil and water resources, its average yield of paddy and wheat are only about 32% and 44 % of the potential yield.(The Asian average is 4.23 t ha^{-1}, while the world is averaging 4.18 t ha^{-1}) (Thiyagarajan, &Gujja, 2013). Considering improvement in agriculture productivity as priority, a series of schemes have been initiated by the government of Bihar, following first agriculture road map (a time bound policy document). The focuses of these schemes are improving agriculture productivity and farm income in Bihar. One such programme regarding productivity improvement in Bihar is SRI (system of root intensification), covering both aspects of technology and inputs.

The *System of Root Intensification,* is a climate-smart, agro ecological methodology for increasing the productivity of paddy and more recently other crops by changing the management of plants, soil, water and nutrients. SRI methodology is based on four main principles that interact with each other: (1) early, quick and healthy plant establishment, (2) reduced plant density, (3) improved soil conditions through enrichment with organic matter, (4) reduced and controlled water application. Based on these principles, farmers can adapt recommended SRI practices to respond to their agro-ecological and socio-economic conditions. Adoptions are often undertaken to accommodate changing weather patterns, soil conditions, labour availability, water control, access to organic inputs, and the decision whether to practice fully organic agriculture or not.

The principles of SRI, which are fundamental to achieving the expected benefits, are following:

(1) Very young seedlings should be used, to preserve the plant's inherent growth potential for rooting and tillering;

(2) Transplanting single seedling per hill should be done quickly, carefully, shallow and skilfully, in order to avoid any trauma to the roots, which are the key to plants' success;

(3) Reduce the plant population radically by spacing hills widely and squarely, so that both the roots and canopy have room to grow and can have greater access to nutrients, sunlight, etc.;

(4) Provide growing plants with sufficient water to meet the needs of roots, shoots and soil biota, but never in excess, so that the roots do not suffocate and degenerate;

(5) Active soil aeration improves paddy crop growth in order that both roots and beneficial aerobic soil organisms are in benefit;

(6) Augmenting organic matter in soils, as much as possible, improves performance of the paddy crop, by improving soil structure and functioning and supporting beneficial soil organisms.

Each of the six principles of SRI has an important bearing on the performance of the crop. Detail benefits of SRI method are discussed in Table 1 and Figure 1. The overall

effect of adopting SRI practices is an increased grain yield, which can be obtained irrespective of the variety planted (Thiyagarajan, &Gujja 2013).

Studies show that SRI method uses 30-50% less water (Thiyagarajan et al., 2005; Mahenderkumar et al., 2010; Thakur et al., 2010; Zhao et al., 2010), 60-80% less seed (Kumar et al. 2010; Styger et al. 2011, WWF-ICRISAT, 2008.), 10-25% less use of labour (Anita, Chellappan, 2011; Thiyagarajan et al., 2005). It has been widely accepted that SRI is a cost saving method and net income increases is possible up to 80-165% (Thiyagarajan et al., 2005; Radha et al., 2007, WWFICRISAT, 2008) as production increases up to 10-90%10 to 90 percent at a lower cost. On the other hand, linkage between the nutrition and output produced, using SRI is also high, as it has been found that cereals produced using SRI has high nutrient content than non-SRI methods produced cereals (Barison, & Uphoff ,2011).

Table 1: Significance of SRI Principles

Principle	Significance
1. Young seedlings	Much greater potential for tillering and root growth • Earlier arrival within a better growing environment in the main field extends the time for tillering • No transplanting shock if transplanting is done carefully.
2. Single seedling per hill	No competition for nutrients, water and space within a hill • Seed requirements are reduced • This practice combined with wider spacing enables all leaves to be photosynthetically active; whereas with crowding, lower leaves do not get enough exposure to sunlight for photosynthesis. This deprives the plant – and especially the roots – of possible supply of photosynthesis.
3. Wider spacing	Promote more profuse growth of roots and tillers • More space (below and above ground) per hill for access to nutrients, water and light • Inter-cultivation with mechanical weeder is made possible.
4. Moist and unflooded water management regime	Non-hypoxic condition of soil favours root health and functioning, and supports more abundant and diverse communities of beneficial aerobic soil organisms • No degeneration of roots, which otherwise will be as much as 75% degraded by panicle initiation under flooding • Exposing the soil to sunlight is favourable for warmth • Water savings of up to 40% • Energy saving where water is pumped.
5. Inter-cultivation	Churning up of the soil activates the microbial, physical and chemical dynamics • Triggers greater root growth and tillering • Weed biomass is incorporated into the soil as green manure • Weeding costs can be reduced.
6. Liberal use of organic manures	Gives better plant growth response than inorganic fertilizers • More sustained supply of nutrients • Favourable growth of soil biota • Enrichment of soil health.

Source: Uphoff, 2008

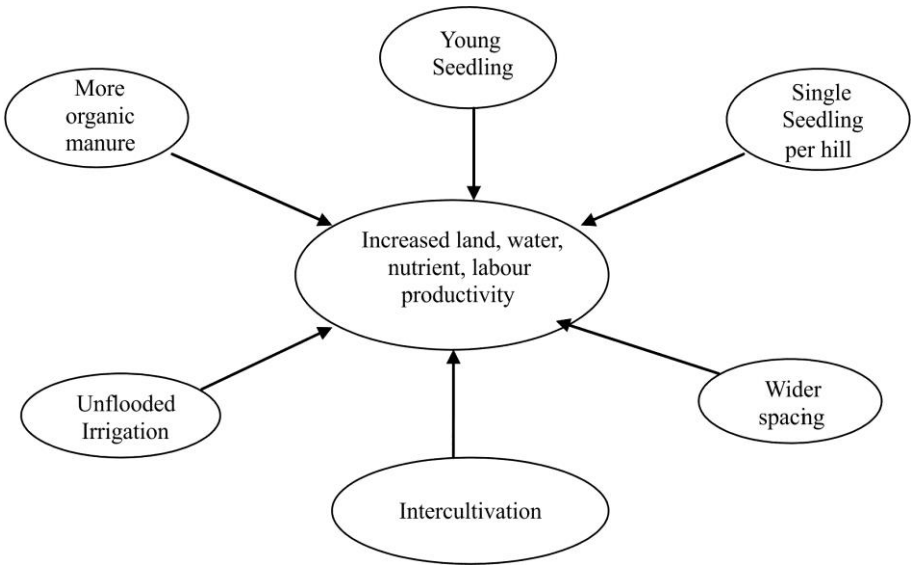
Actual return to SRI depends on several factors, such as farm and farmer characteristics rather than the technology itself (Barrett et al., 2004). Overall findings reveal that SRI

method has high potential and it can have more significant change in productivity if other socio-economic factors are also in favourable condition. However, Alagesan & Budhar (2009) found that farmers faced difficulties in large-scale adoption of SRI in Tamil Nadu, India, because of the knowledge deficit and labour shortage. Moser and Barrett (2002) found in their study, in Madagascar, that SRI higher labour needs and seasonal liquidity constraints, social conformity also play major role in low adoption of new technology like SRI.

Since the benefits of SRI in terms of productivity are higher and the cost of production is also lower than the other conventional method, the government of Bihar is promoting farmers to use SRI practice in the crop production. Despite policy support has been extended by state Government, still the adoption of SRI has been restricted to some farmers. Besides, findings presented above showed significant role of SRI in increasing cereal productivity, while any evidence based study on Bihar was not available. The central question of the present study is why SRI method adaptation is lower in Bihar, where most of the farmers are confronted with low income and low agriculture productivity.

In this backdrop, this study covers debate on SRI and ground realities with the help of field visits and interaction with farmers in Bihar, state of India. This study is divided into three sections. First section discusses data and methods. Second section presents results. Third section provides discussion and conclusion.

***Figure 1**: SRI Hexagon*



Source: Uphoff, 2008

Section I . Data & Methods

To increase the productivity of agriculture by using less resource, Government of Bihar has introduced a number of schemes for the agriculture road maps and SRI practice promotion is one of them. Under SRI promotion scheme, government of Bihar provides SRI kit, including seeds, micro nutrients, bio-fertilizers, conoweeder etc., following a promising demonstration of SRI practice at Panchayats, at block or district level to farmers in Bihar. In the farmers selection, priority is given to Scheduled Castes (SC) & Scheduled Tribes (ST) and women. The government claims that it has resulted in higher yield and higher income.

This study seeks to find out effects of SRI practice on agriculture of Bihar and reason for low adoption. The study is based on primary data collected from 14 districts of Bihar (Begusarai, Dharbangha, East Champaran, Gopalganj, Khagaria, Madhubani, Muzaffarpur, Sheohar, Smastipur, Saran, Sitamarhi, Siwan, Vaishali, and West Champaran). A multi-stage – stratified – purposive – random sampling design was adopted in the study. The sample household were selected from fourteen districts of Bihar. From each district, two blocks having highest number of beneficiaries were selected. In selected blocks, two Panchayats rather than villages selected based on the highest number of beneficiary. From each Panchayat, 15 sample household were selected based on stratified random sampling method. From each district, 60 farmers were selected. A total of 840 farm households were surveyed.

The process of the farmer's adoption has raised a serious debate and numerous hypotheses have been tested to identify its casual viewpoints. The major hypotheses put forwarded in the literature are "Market incentives hypothesis"," Non-Market incentive hypothesis" and "Time factor hypothesis". Several studies have tested these hypotheses and identified a large number of factors, explaining the adoption practices of farming households. These includes financial reasons (Wilson and Hart, 2000), farmer's Attitude (Ajzen & Fischbein, 1980; Artikov et al., 2006; Elliot et al., 2011; Burton et al., 2006), farming system (Barnes et al., 2011), geographical factors (Burton et al., 2006), farm size (Manley & Smith, 2007; Defrancesco et al., 2007), demography of farming household (Ahnstrom et al., 2008), socio-economic, psychological and social and psychological factors (Willock et al., 1999a, 1999b) (Burton, 2004). This paper seeks to test above mentioned hypothesis to explore the farmer's adoption of SRI method in Bihar.

To analyse the determinants of farmer's adoption of SRI method in paddy and wheat, logit models have been used, in order to estimate the probability of a farmer to adopt SRI method. Details of explanatory variables are given in Table 2.

Table 2: Detail of Explanatory Variables

Sl. No.	Variable	Detail of Variable
1	SRIR	Does the farmer adopt SRI in paddy cultivation
2	SRIW	Does the farmer adopt SRI in wheat cultivation
3	AGE	Age of the farmer
4	LAND	Type of the farmer
5	LITERACY	Years of education from primary to Master degree
6	GENDER	Gender of the farmer
7	SOCCLASS	Social category of the farmer

Section II. Results

Household Characteristics Findings

The risk behaviour of farm household is determined not only by preferences, but also by the availability of institutions and psychological factors or decision costs of peasant production choices (Roumasset, 1976; Eswaran & Kotwal, 1986; Morduch, 1994; Duflo, 2003). In farm economy of Bihar, there are non-market forces, such Castes, that decide access to land (by the Law of inheritance) and play significant role in agriculture production dynamics. Here, access to government schemes also depends on the Castes and land holding dynamics of farm households in Bihar.

Besides the fact that SRI method has significant bearing on productivity, only about 52 % of selected total sample of farm households were using SRI practise in paddy cultivation. Similarly, about 35 % of selected sample of farm households were using SRI practice in wheat cultivation (Table 3). Use of SRI method was higher in paddy cultivation than in wheat cultivation. Landholdings' wise distribution of SRI practitioners gives another significant picture. In all, preference for SRI in paddy and wheat cultivation among small and large farmers was higher than the others (Table 4).

Under the SRI scheme, Government of Bihar provides not only SRI kit to the farmers, but also financial supports to purchase farm machines. Analysis of all sample beneficiaries shows that small farmers, medium and large farmers received the benefit of the SRI kit, but access to financial support for buying agriculture machines, horticulture and others was comparatively higher among large and medium farming households. Findings show that large landholders mostly prefer labour saving techniques and concentrate on commercial farming, instead of investing in new methods, like SRI. The distribution dynamics of SRI kit also shows different situation. The detailed assessment of beneficiary of different schemes reveals the fact that financial support was given for buying those machines, which were useful for large or medium landholders. On the other hand, the amount of support was low for machines like threshers or tractors, therefore most of the benefits under mechanisation supports were used either by large or by medium farming households.

Gender wise distribution shows that access to all supports was higher among male farmers, as 96% of beneficiaries were male. Here, composition of households in Bihar may be responsible for the male biases nature of the outcome. Recent census data show that about 7% of total households in Bihar are headed by women, which is lower than all Indian figures. On the other hand, benefits were mostly distributed at block or district level and it was difficult for female farmers to collect those benefits outside their villages, thus percentage of female beneficiaries was lower in these districts.

Table 3: Distribution of Sample (in %)

Access	SRI Paddy	SRI Wheat
Adopter	52.5	35.83
Non-adopter	47.5	64.16

Source: Primary Survey Data

Table 4: Landholding Wise Distribution of SRI Adopter Farmers in Bihar (in %)

Beneficiary categories according to landholding	SRI Paddy	SRI Wheat
Less than 2.5 acres	16.10	16.28
2.5 to 5 acres	37.87	39.53
More than 5 and less than 10 acres	22.90	19.93
More than 10 acres	23.13	24.25

Source: Primary Survey Data

Literacy and caste play important role in the agrarian economy of Bihar. Access to education, especially quality education, plays significant role in the discrimination and level of awareness in society in Bihar. It has found that literate farmers have greater access to information and receive greater benefits of any government support. Similarly, under SRI scheme, literate farm households had higher access to SRI kit in Bihar (Table 5). Social category wise distribution shows (Table 6) that preference for SRI was higher among general and OBC's (Other Backward Castes) farm households than others.

However, SRI is an innovative method of cultivation; its use is depending on several factors, including demand and supply sides. In all, supply side factors were playing main role in use of SRI method in Bihar. However, supports like SRI kit was attractive for small and marginal farmers, the benefits were not higher in terms of money and binding to use SRI method at least in one acre for the beneficiary of SRI kit, large and medium land holdings farm household were not much interested in absorbing the benefits of SRI kit or use of SRI in cultivation.

Table 5: Literacy Wise Distribution of SRI Adopter Farmers in Bihar (in %)

Level of Education	SRI Paddy	SRI Wheat	Level of Education	SRI Paddy	SRI Wheat
Illiterate	4.76	5.98	**Graduation**	20.63	21.93
Primary	7.03	7.64	**Master Degree**	3.63	3.32
Middle	10.43	11.63	**ITI**	0.45	0.66
Secondary	34.01	31.23	**B.Ed.**	0	0
High secondary	19.05	17.61			

Source: Primary Survey Data.

Table 6: Social Category Wise Distribution of SRI Adopter Farmers in Bihar (in %)

Social Category	SRI Paddy	Sri Wheat	Social Category	SRI Paddy	SRI Wheat
General	44.22	48.84	**Minority**	1.81	1.99
OBC	45.35	42.52	**Mahadalit**	3.17	1.66
SC	3.17	2.66	**Other**	0.23	0.33
ST	2.04	1.99			

Source: Primary Survey Data.

Effect of SRI on Productivity and Income

This section shows effect of SRI on land use, productivity and farm income of paddy and wheat producer farm households of Bihar. Table 7 shows the effect of SRI on the use of land for paddy and wheat cultivation. It shows that land used for paddy cultivation has increased after SRI intervention. Similar trend can be seen in wheat cultivation. Table 8 shows the changes in yield of paddy and wheat production of SRI farmers. The table shows that the productivity of paddy and wheat has significantly increased after using SRI practices. The analysis shows that small farmers have also experienced similar improvements in productivity, which is a positive sign for policy makers. It was also noticed that productivity gain in paddy after using SRI has also attracted farmers to cultivate more paddy than the previous year. Table 9 shows the effect of SRI on sale of wheat and paddy. The table shows that sale of wheat and paddy has increased after using SRI. However, effect of SRI in terms of marketable surplus on the production of wheat cultivation was less satisfactory.

Table 7: Pattern of Land Use for Paddy and Wheat Cultivation by SRI Adopter Farmers in Bihar (in %)

Beneficiaries Categories According to Landholding	Land used in Paddy Cultivation		Land used in Wheat Cultivation	
	Before Plan	After Plan	Before Plan	After Plan
Less than one acre	26.53	12.8	27.82	13.64
1.1-3 acres	39.29	42.4	49.62	54.92
3.1-5 acres	20.15	27.76	12.03	17.05
5.1-10 acres	11.48	12.8	7.57	10.22
10.1-20 acres	1.79	3.5	2.26	3.79
20.1-40 acres	0.52	1.1	0	0.38

Source: Primary Survey Data.

Table 8: Yield of Paddy, Wheat of SRI Adopter Farmers in Bihar (quintal per bigha)

Beneficiaries Categories According to Landholding	Paddy Cultivation		Wheat Cultivation	
	Before Plan	After Plan	Before Plan	After Plan
Less than 2.5 acres	10.54	17.44	8.58	13.15
2.5 to 5 acres	10.89	17.57	9.09	13.52
More than 5 and less than 10 acres	11.31	18.04	8.97	12.85
More than 10 acres	11.43	17.94	9.97	14.31

Source: Primary Survey Data.

Table 9: Sale reported by SRI Adopter Farmers in Bihar (in %)

Reply	Paddy Cultivation		Wheat Cultivation	
	Before Plan	After Plan	Before Plan	After Plan
Yes	92.97	95.20	89.96	91.03
No	7.03	4.80	10.04	8.97

Source: Primary Survey Data.

Determinants of SRI Method Adoption in Bihar

The results given in table 10 and table 11 confirm expected relationship between age of farmer and possibility of adoption of SRI method in paddy and it is positive for both, paddy and wheat. The strong relationship between age of farmer and possibility of adoption of SRI method for paddy, in comparison to wheat, shows that preference for SRI increases if the farmer produces paddy. The relationship between education and SRI adoption is positive and significant. It suggests that with higher level of education, the probability of using SRI becomes higher. The education makes the farmers capable of understanding the pros and cons outside traditional methods and loosens the barrier in access to SRI. The relationship between land and probability of using SRI method is positive. Large farm households can bear the risk of adopting new methods of cultivation without adversely affecting the agricultural activities. The marginal effect of age on SRI adoption is the highest for both, paddy and wheat. With an increase in the age class of farmers, the probability of access to SRI increases by about 5 to 6%.

Table 10: Determinants of farmer's adoption of SRI method in Paddy Cultivation in Bihar

Particulars	Coefficient	Standard Error	dy/dx	Standard Error
AGE	0.82	0.28	0.063	3.15
LAND	0.14	0.07	0.018	1.99
LITERACY	0.05	0.02	0.006	2.04
GENDER	0.12	0.37	0.093	0.33
SOCCLASS	0.09	0.15	0.037	0.60
Constant	-1.63	0.50		
Log Likelihood	-0.571			
Number of Observation	840			
Chi²	0.001			
R²	0.017			
Correct Prediction	0.52			

Table 11: Determinants of farmer's adoption of SRI method in Wheat Cultivation in Bihar

Particulars	Coefficient	Standard Error	dy/dx	Standard Error
AGE	0.32	2.39	0.056	2.82
LAND	0.08	0.08	0.017	1.11
LITERACY	0	0.02	0.006	-0.01
GENDER	0.45	0.41	0.08	1.2
SOCCLASS	-0.28	0.15	0.036	-1.78
Constant	-1.78	0.56		
Log Likelihood	-542.025			
Number of Observation	840			
Chi²	0.013			
R²	0.013			
Correct Prediction	0.35			

Problem related to SRI in Bihar

This part of analysis is based on the findings of focused group discussion. Focused group discussion is useful because it gives a better idea about the change in behaviour of farming household and it also suggests potential solution to the problem. Interactions with beneficiary farmers and non-beneficiary farmers reveal major concerns regarding SRI practices in Bihar. Debates about the adoption of SRI practices were mostly focused on the fact that SRI is more-*labour intensive* than conventional methods. During interactions, it was reported by a large number of farmers, especially medium and large farmers, that SRI practice is labour intensive and needs extra attention because it is not common until now. It was noticed during interactions that concern regarding SRI was misinterpreted by some farmers. Another major concern was reported by the farmers that SRI is a more rigorous and exact regime that needs precision-timed operations and constant supervision. Unavailability of trained labour was reported as a serious problem, because government concentration on training of agriculture labour was missing in the programme of Government of Bihar. Lack of specifications regarding the designs of conoweeder appropriate for different soil types also appeared as a serious problem. Besides, SRI practice is applicable in rain-fed paddy and wheat, and to other crops, such as sugarcane, finger millet, pulses, showing increased productivity over current conventional planting practices; however, this study finds that SRI principles were applied only for paddy and wheat in Bihar. It was also found that in most of the cases only those farmers who received SRI kit, were using SRI . Most of the non-adopter farmers were telling that they were not practicing SRI, because government did not give thembenefits of SRI kit. Overall, it was seen that in most places farmers are using SRI practice because of binding of use of SRI method on at least one-acre land under the SRI kit scheme. This shows that besides support of the government, the level of social awareness about the benefits of SRI is not up to the level. In several studies, it has been demonstrated that the role of civil societies in information/ dissemination is important. Unfortunately, the involvement of civil society to promote the use of SRI was missing in Bihar.

Section III. Discussion & Conclusion

Farmers and policy makers have long time focused on improving the yield in agriculture as an effective way of improving food security since independence. Up to previous decade, most of the policy supports were concentrated on inputs oriented mechanism to increase yield of crops in Indian states like Bihar. In absence of context specific development strategy, the policies support towards agriculture has resulted in an uneven growth pattern in terms of productivity of crops, such as paddy and wheat, across the states. Due to additional emphasis on the use of natural resources like water, India is close to the limits of water shortage in many states including Punjab, Tamil Nadu. Under the present situation, increase in poverty is expected, if diversification towards other livelihood sources or improvement in the use of scarce resources in a sustainable manner is not being promoted. Under the sustainable livelihood framework, most of the policies are concentrating on the promotion of diversification towards noncereal production in agriculture, in India's states, in recent decade and stress on paddy and wheat land is indirectly increasing, day by day. Under this situation, the need

of the present time is to produce more paddy and wheat, using few resources, such as less water and less land. One of the promoting methods, under which more production is possible using similar amount of land and less inputs, is SRI. However, some of SRI principles, such as practices of single seedlings and wider spacing has been in practice by the paddy farmers of Tamil Nadu in India (Thiyagarajan & Gujja, 2009) for a long time. The first structured invention on SRI was made in the year of 2000 and it has been followed by trials, in several states, including Bihar after the year of 2000.

This study examines farmers' views on SRI regarding and its effect on paddy and wheat production in Bihar. This study finds that preference for SRI is higher among experienced farmers than younger farmers in Bihar. The analysis also confirms the role of literacy in promoting farmers to use SRI in agriculture in Bihar. Productivity of paddy and wheat has increased significantly after using SRI practices. Limitations reported by the farmers are lack of awareness, labour intensive nature of SRI, shortage of skilled labour and absence of proper machines, useful for different types of soil. The findings of this study support that supply-side factor is playing a major role in the adoption of SRI practise in Bihar. Due to the low role of demand side factors, the adoption of SRI is still low in Bihar.

Proper demonstration of SRI practices may have significant bearing on the use of SRI practice in Bihar. Training of agricultural labourers especially about SRI techniques and use of green fertilisers etc. can promote more farmers to use SRI practice (need of skill development in agriculture). Village teachers or educated people can be trained to work as local resources to promote the use of SRI practice, efficiently and more beneficially. Involvement of civil society (with incentives) may promote SRI practices in Bihar. Recognitions of successful farmers at block level, district level and state level can also promote farmers to use SRI practice. [1]

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