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FULL-LENGTH RESEARCH ARTICLE

Adoption of Modern Rice Cultivation Practices in Bihar, India: Micro-level Evidences from Village-Level Studies

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Abstract This study was conducted to understand the adoption of improved technologies and cultivation practices in rice production in Bihar. The study is based on the high-frequency field-level data being collected under ICAR-ICRISAT project on village dynamics studies in South Asia. The findings of the study show that the adoption of modern technology is directly related to the size of holding. The inverse relationship between productivity and farm size has ceased to operate in recent years. This study reaffirms this trend. The study suggests for designing appropriate and implementable agrarian policies with strong monitoring and evaluation framework to accelerate the speed of adoption of modern technologies to enhance rice productivity in eastern India in general and Bihar in particular.

Keywords Rice · Adoption · Improved seeds · Bihar

Introduction

Bihar is the third most populous state of India after Uttar Pradesh and Maharashtra. Globally, only 11 countries in the world have a population greater than Bihar. The state is still crippled with high prevalence of poverty and undernourishment, and low agricultural productivity [10]. Bihar's per capita income has persistently been lower than any other state in India. The per capita income in 2011–2012 was Rs. 13,303, about 40 percent of the all-India average [2, 6]. This is attributed to several factors such as high dependency on agriculture, limited access to productive assets (such as land and livestock), education and health care, as well as lack of remunerative employment opportunities [5, 9]. Agriculture engages over two-third of the state's total workforce, and therefore, the enhancement in agricultural productivity is crucial for the welfare of the state populace.

Rice is the most widely consumed (72 kg/person/year), produced (43 % of GCA) and valued commodity (16 % of AgGSDP) in Bihar. It is a staple food of almost all the population of Bihar and provides food security and livelihoods to majority of the farming households. With a rice land of about 3.3 million ha, Bihar is the sixth-largest rice-growing state, accounting for 8 % of area and contributing 7 % to the national rice production. But the yield of this important crop remains one of the lowest in India [2]. The low rice yield can be attributed to a number of factors including the lower adoption of modern technologies [8, 9]. However, the recently launched agricultural development projects such as National Food Security Mission (NFSM) and Rashtriya Krishi Vikas Yojana (RKVY) have been promoting the extensive use of modern rice technologies in Bihar. The adoption of improved rice technologies and crop management practices are providing opportunities for farmers to increase rice production, which in turn improves the income and food security of rice farming households. The important technologies being promoted during the last

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5 years include adoption of modern rice varieties (including hybrid seeds), balanced use of fertilizers, water management technology (frequency of irrigation) and proper age of seedling for transplanting and appropriate farm implements [15, 16]. In fact during the last 5 years, Government of Bihar made significant efforts to popularize modern rice technologies for improving rice yield and increasing rice production in the state and the seed replacement rate or adoption of improved certified seeds has gone up considerably. But the adoption of different packages of technologies by farmers is only partial, and all farmers are neither able nor willing to adopt new technologies due to several socioeconomic, institutional and environmental constraints. Understanding the constraints to technology adoption is a precondition to evolve strategies for effective dissemination of farm technologies. The present study aims to assess the extent of adoption of certified seeds and other improved crop management practices. More specifically, the present study has two objectives: (1) to examine extent of adoption of certified improved rice seeds and other crop improvement practices in the selected villages and (2) to identify factors influencing adoption of certified rice seeds.

The rest of this article is organized as follows. The next section describes the materials and methods used in the study. Section 3, after giving a brief on performance of rice production in Bihar, presents results and discussion of the study, while Sect. 4 provides conclusion of the study.

Materials and Methods

Materials

This study is based on the high-frequency primary data collected at household, individual and plot level by resident investigators over 3 years under the ICAR-ICRISAT collaborative project on 'Tracking Change in Rural Poverty in Household and Village Economies in South Asia.[1]' During data collection, the resident investigators reinterview the households several times in a year so as to capture the dynamics of households including the farming practices.

The data used in this paper pertain to four villages in Bihar (Arap and Bhagakole villages of centrally located district of Patna and Susari and Inai villages of Darbhanga district, located in northeastern region of Bihar). For drawing a representative sample, sampling was done in five steps. First, all the households in a village were grouped in four categories. The first group was made with household having <0.2 hectare (ha). These household were termed as labor households. In the second step, the remaining households were equally distributed among tertile group with the bottom, middle and top groups being referred to as 'small,' 'medium' and 'large' households, respectively.

Thus, four groups were created for each village. We selected 10 households from each group randomly, which makes up 40 sample households per village and 160 household for all the four sample villages. Out of these 160 households, 116 households were involved in cultivation of rice. Since focus of this study was to identify the factors that influence adoption behavior of farmers in the context of rice cultivation, the analysis was carried out for these 116 households. These 116 households were further categorized into sub-marginal (<0.40 ha.), marginal (0.4–1 ha.) and small farm households (1 ha. and above). This helped to understand the scale relationship in the adoption of modern rice cultivation practices.

Methods

The purpose of this paper is twofold. The first aim is to assess the extent of adoption of certified seeds, application of fertilizers, irrigation and improved/recommended practices such as age of seedlings during transplantation and other improved cultivation practices. The second aim is to identify the determinants for decision of the farm households to adopt (or not adopt) modern technologies such as high yielding varieties (HYVs) or certified improved seeds (and seed replacement). Three year's average of adoption of different technologies and practices were taken to minimize the year to year variations in level of adoption and thus to get more reliable estimates.

Logit and probit models are widely used to assess the functional relationship between the probability of adoption and its determining elements (such as resource ownership, education, social strata and farm size). The binary models enable a more specific analysis of farmers' adoption decisions of a technology. This type of analysis provides more detailed information on the characteristics of farmers who would adopt a specific technology. Several analysts have employed this approach [3, 11–13, 19]. We have used panel logit model to find out determinants of rice seed replacement in the study area. In the logit model, the households are assumed to make decisions based upon the objective of utility maximization. Since the dependent variable Y is binary, with values 0 and 1, and the independent variables are a mix of qualitative and quantitative variables, the multivariate logistic regression given in Eq. (1) was used:

[1] The VLS are longitudinal surveys initiated by ICRISAT in 1975 in six Indian villages. The surveys continued for the next 10 years, before formally closing in 1985 in response to budgetary pressure. The surveys were reopened in 2002 in the initial six villages, starting with low-frequency rounds and with higher-frequency interviews since 2005–06. Subsequently in 2010, the coverage was enhanced by including 12 villages in the eastern India with funding from the Bill and Melinda Gates Foundation. The VLS data, however, cannot be treated as representative data for districts, states or the agro-climatic region within which the villages are located due to the relatively small sample coverage.

$$Y = \ln[p/(1-p)] = \beta_o + \sum \beta_i X_i \quad (1)$$

where p represents the probability that the farmers are replacing seed each year and $\underline{\beta_{is}}$ are the regression coefficients estimated by the maximum likelihood method. The explanatory variables used in the model included gender, age, education, size of holding, extent of irrigation.

Results and Discussion

Performance of Rice in Bihar: Macro-trends

The long-term macro-trends observed through several decades suggest declining area under rice cultivation while the production for the same period remained stagnant (Table 1). The rice yield has grown at about 1 % per annum since 1990–1991. However, the pace of the productivity growth itself has declined in the last decade, and therefore, yield has improved at a snail pace over time—roughly 10 kg/ha annually and thus stood at around 1600 kg per ha during 2011. This is critical issue to know because of the fact that the productivity of rice in Bihar has been historically poor with estimated current yield gap of over 1 tone per ha, which, if met, could lead to an increased production of about 3 mt of additional rice that could roughly take care of the food requirement of more than 40 million people round the year [9, 17].

However, recent estimates suggest Bihar farmers have taken up the challenge seriously and recorded quantum jump in the production and productivity of rice. The spectacular increase in the rate of seed replacement from 12 % in 2006 to nearly 40 % in 2012, and adoption of innovative methods such as SRI apart from other developmental factors may be attributed to huge gains in the rice productivity (Table 1).

A good undercurrent of development on the productivity front can also be seen at the disaggregate level (Table 2). Observations of spatial changes in rice productivity suggest the area under low productivity has been decreasing continuously over the recent two decades; from close to 60 % area under <1000 kg/ha in TE 1991–1992, the scenario reversed to >2000 kg/ha for about 63 % of area under rice in TE 2011–2012. The rice productivity in 40 percent of rice area is more than national average. It appears that the adoption of improved rice technology by farmers in Bihar during the last 5 years which was made possible because of investment in extension efforts of state government through various mega projects such as NFSM, RKVY and BGREI has had a significant payoff.

Table 1 Area, production and yield of rice in Bihar. *Source* Authors' calculations based on Govt. of Bihar, http://krishi.bih.nic.in

Year (TE)	Area (million ha)	Production (million tons)	Yield (kg/ha)
1991–1992	3.8	4.5	1201
2001–1902	3.2	4.5	1377
2012–2013	3.1	5.0	2202
CAGR (%)			
1991–1992/2001–2002	−3.0	0.0	3.1
2001–2002/2011–2012	−1.3	0.7	2.0
1991–1992/2011–2012	−0.4	0.5	0.9

Table 2 Proportion of rice area with different level of productivity, 1990–1991/2011–2012 (Area in %). *Source* Authors' calculations based on Govt. of Bihar, http://krishi.bih.nic.in completely realized by the sub-marginal farmers

Productivity level (Kg/ha.)	TE 1991–92	TE 2001–02	TE 2011–12
<1000	59.7	13.3	0.0
1000–1500	35.2	51.7	5.9
1500–2000	5.1	18.2	31.0
2000–2500	0.0	16.8	25.3
≥2500	0.0	0.0	37.9

This rice productivity gain seems to be widespread in Bihar, and the gains of productivity are spatially gaining grounds. This is all the more important because Bihar is dominated by small and marginal farmers.

Adoption of Improved Technologies and Practices

In sample villages, only kharif rice is grown, which covers about 50 % of cultivated area. Following subsections throws light on the use of different inputs and other cultivation practices by the sample farmers namely—seed replacement and management, fertilizer use, irrigation and water management.

Seed Replacement

Seed is the most important determinant of agricultural production on which depend the performance and efficacy of other inputs. Sustained increase in rice production and productivity necessarily requires continuous development of new and improved rice varieties and efficient system of production and supply of seeds to farmers. Government of Bihar has made massive efforts in recent years for increasing seed replacement rate for augmenting rice production in the state. The impact gradually showed up, and the seed replacement rate increased from mere 7 % in 2001–2002 to 12 % in 2006–2007 and progressively to 38 % in 2011–2012 [15, 17]. This is a significant accomplishment by any standard. We witnessed this macro-trend in the sample villages too where we studied the replacement rate for 2010 through 2012. Seed replacement rate showed a direct relationship with the size of holding. However, the impact on productivity has been outstanding for all the groups and the difference in the productivity level is close to 2000 kg/ha. However, due to numerous agrarian and socioeconomic factors the seed replacement potential has not been completely realized by the sub-marginal farmers. There might be several reasons such as seed economics, seed availability/accessibility, resources, credit situations, profitability and even socioeconomics that has not allowed the farmers with average 0.4 ha of land to improve the replacement rate beyond 31 % (Table 3). One of the issues is of drying of the availability of subsidized seeds which may constrain the sub-marginal farmers for adoption of modern certified seeds.

Age of Seedlings

Age of seedlings for transplantation of rice is one of the important dimensions for improving overall performance of a crop, and it has been amply proved by some of the best practices such as System of Rice Intensification (SRI) that it immensely contributes to improving productivity of the crop. And therefore age of the seedlings for transplantation is now considered one of the most important cultural interventions the world over. Amin and Haque [1] found the maximum yield of rice when seedlings of 27 days were transplanted. Rahimpour et al. [14] found the yield touching the peak when seedlings of 35 days age were transplanted. In our study, we found similar results with seedlings close to 30 days old ensuring higher productivity gains. Extent of rice area transplanted by seedlings of different age groups is given in Table 4. It should be noted that while sub-marginal farmers who have maximum holding in the area go for seedlings of age between 30 and 40 days, their counterparts who are better area-wise and resource-wise go far seedlings close to 30 days. Very less area under rice (14 %) is transplanted with seedlings older than 40 days, which varies from 10 % in case of small holders and 31 % in case of sub-marginal farmers.

Table 3 Adoption of certified seeds and its impact on rice yield. *Source* Authors calculations based on VDSA field survey, 2010/2011–2012/2013

Particulars	Seed replacement rate (%) TE 2012	Yield (kg/ha)	
		With_SRR	Without_SRR
Sub–marginal (< 0.4 ha.)	30.9	5227.9	3245.1
Marginal (0.4 to 1 ha.)	47.0	5973.1	3459.9
Small–medium (1 ha. and above)	57.1	6159.3	3783.2
All	40.3	6119.9	3595.8

Table 4 Proportionate area transplanted by different age of seedlings (% rice area). *Source* Authors calculations based on VDSA field survey, 2010/2011–2012/2013

Holding group	Close to 30 days	30–40 days	40 days and above
Sub-marginal	12.8	55.7	31.5
Marginal	11.7	69.0	19.3
Small-medium	53.2	36.9	9.9
All	40.3	45.8	13.9

Table 5 Use of fertilizers (N+P+K) in rice production on different categories of farms (kg/ha). *Source* Authors calculations based on VDSA field survey, 2010/2011–2012/2013

Particulars	(N+P+K)	N	P	K
Sub-marginal	90.0	83.5	4.9	1.6
Marginal	95.8	83.9	7.1	4.8
Small–medium	145.4	117.8	16.0	11.6
Average	128.3	106.2	13.0	9.1

Owning assured irrigation facilities has been found to have a direct link to transplantation of seedlings of appropriate age, whereas majority of sub-marginal and marginal farmers had to purchase irrigation water from fellow farmers which was not easily available at desired time.

Fertilizer Use

The use of fertilizer at the state level picked its pace during early 1980s when the meagre 20 kg/ha use of this critical input broke the barrier of 50 kg/ha. Since then, the use has only grown and grown at a phenomenal pace of about 30 % annually. The latest figure suggests that Bihar farmers are using close to 180 kg fertilizer per hectare. However, the sub-marginal and marginal group of farmers in our sample expectedly got featured using lower per unit fertilizer while the small–medium category fertilizer use stood close to national-level average of about 150 kg/ha (Table 5). Sub-marginal group of farmers uses over 60 % less fertilizers on their farms.

However, the use of potashic and phosphoric fertilizers has been critically low at sub-marginal level and much below (almost one-sixth) the state and national average. Thus, there is a case for imbalance use (NPK–11.7: 1.4: 1) of fertilizer largely skewed toward nitrogen application.

Water Management

Around 55 % gross cropped area in Bihar receives irrigation although the quality, resource and quantum of irrigation differ spatially, temporally as well as among various size groups. The sub-marginal and marginal farmers are again at disadvantage due to the fact that the ownership of the irrigation equipment is directly related to the size of holdings. Repeated drought years have made the condition for sub-marginal groups worse in the recent times. However, majority of farmers give survival irrigation in the state to save rice crops from severe moisture stress. Bore well is the main source for rice cultivation and 56 % farm households under study own bore well.

Almost all farm households under study cultivated irrigated rice; however, the number of irrigation ranged from one to nine. Rice area under different frequencies of irrigation (one to more than five) was computed for all the three categories of farm households under study (Table 6).

Analysis of data relating to number of irrigation to rice crops revealed that about 40 % of rice area was irrigated once or twice in study villages, whereas 46 % rice area got 5 and more irrigations, indicating much variation in availability of water to rice crops in study villages. Sub-marginal farmers irrigated once or twice their 75 % of rice crop and only 6.7 % of their rice area could get five and more irrigations in study villages. Small–medium farmers could arrange five and more irrigation to their 56.4 % of rice area. There was wide variation in number of irrigation to rice crop between categories of farm households. It was mainly due to status of ownership of irrigation resources on different categories of households. About 73 percent of small–medium households own bore well and the majority of them irrigated their rice crops more frequently, whereas 98 % of sub-marginal farmers do not own bore well and purchased water from fellow farmers and provided survival irrigation to their 75 % rice crops due to costly irrigation (Rs. 2000/per ha./per irrigation).

This is largely due to the ownership of the irrigation resources as explained earlier. In our sample, only 2 % of the sub-marginal farmers owned bore wells, the rest purchase water from the fellow farmers at a cost of Rs. 2000/ha/irrigation, while 73 % of the small–medium farmers have their own bore wells [15, 16].

Table 6 Number of irrigations to rice cultivation in different plots (% area). *Source* Authors calculations based on VDSA Field Survey, 2010/2011–2012/2013

Particulars	1	2	3	4	≥5
Sub-marginal (<0.4 ha)	26.9	48.4	15.9	2.1	6.7
Marginal (0.4–1 ha)	27.5	28.0	11.6	2.8	30.1
Small–medium (1 ha and above)	13.7	16.3	6.7	6.9	56.4
Total	18.0	21.7	8.6	5.5	46.2

Determinants of Adoption of Certified Seeds

Table 7 presents results estimated from the panel logit model. The estimation is done by the maximum likelihood method with the model being significant at 1 % level of probability. The Chi-square results show that likelihood ratio statistics is highly significant ($P < 00001$), suggesting that the model has a strong explanatory power. The likelihood ratio test statistic results of the model indicate that the size of farm holdings, ownership of irrigation resources, age, education and caste are statistically significant determinants for adoption of certified modern seeds.

Relationship between adoption of modern technologies and farm size is inconclusive though majority of the studies indicated positive relationship [8]. In our farm, size of households is one of the factors affecting seed replacement practices positively. It implies that the larger the size of

Table 7 Panel logit coefficients and standard errors of different variables determining rice seed replacement in study villages. *Source* Authors calculations based on VDSA field survey, 2010/2011–2012/2013

Dependent variable—seed replacement in rice cultivation (yes—1, otherwise—0)		
Explanatory variable	Coefficient	Standard error
Age (years)	0.1258*	0.0726
Age square (years)	−0.0012*	0.0007
Family size (no.)	−0.0456	0.0438
Education (above 10th—1, otherwise—0)	0.5686**	0.2750
Operational holding (ha)	0.2473***	0.0846
Caste (forward caste—1, otherwise—0)	0.9282***	0.3365
Pumpset (having pumpset—1, otherwise—0)	0.2056	0.02884
Members association/organization (yes—1, otherwise—0)	−0.1930	0.3121
Village dummy (Arap—1, otherwise—0)	−0.6419	0.4144
Village dummy (Bhagakole—1, otherwise—0)	−0.4833	0.4119
Village dummy (Inai—1, otherwise—0)	−1.0093**	0.4095
Income from non-farm (Rs.)	0.0000	0.0000
Access institutional credit (yes—1, otherwise—0)	0.1569	0.3269
Constant	−1.8180	2.0336
/lnsig2u	−0.9311	0.8634
sigma_u	0.6278	0.2710
Rho	0.1070	0.0825
No. of observation	483	
Log likelihood	−231.7016	

***, ** and * indicate significance at 1, 5 and 10 % level, respectively farm holdings, the higher the probability to replace rice seed. It might be due to their relatively strong financial strength, more access to seed market and larger resource base. Their comparatively stronger financial strength has prompted them to take risk also in adoption of new rice seeds which is reflected as much greater area under improved practices. Seed replacement rate was much lower in Bihar up to mid of the last decade (7 %), but government launched a massive program for seed replacement in 2008 and well-to-do farmers reap the benefits of new technology during the initial phases. As the technology become more diffused and use intensified, small farmers catch up and begin to benefit more than large farmers [7]. However, the positive relationship between farm size and seed replacement rate suggests institutional or policy interventions to reduce scale barriers for seed replacement rate.

It is expected, the model suggests, that the likelihood of adoption of modern rice technology would increase when rice farmers have good access to irrigation infrastructure. The positive and statistically significant coefficient of ownership of pumpset in the above analysis confirmed this hypothesis. It must be recalled here that 73 % small–medium farmers in our group who own anywhere above a hectare farm land also own their own bore wells and could easily regulate their irrigation requirement. However, as the farm size decreases, the ownership of the bore well shrinks impacting badly on the adoption behavior with respect to improved technology. The success of the Green Revolution including adoption of modern rice variety was made possible by massive investment in irrigation facilities. In Bihar, canal irrigated area has declined due to poor maintenance and new major irrigation project has not been undertaken during the last two decades due to high cost. Hence, one way to increase the adoption of rice seed replacement practices and further increase rice production is the establishment of shallow tube wells and surface water pumps in Bihar.

Caste is an important social factor which is likely to influence the adoption of modern agricultural technology including seed replacement rate. In our model, caste turns out to be, as was anticipated, the significant explanatory variable at 1 % level. This goes to prove that in areas where we witness high social hierarchy, there is all likelihood that lower groups would be at tremendous disadvantage if the 'business as usual' prevails [18]. Thus, we see, in our study that as soon as the government-sponsored (or even NGO- and private party-sponsored) welfare/promotional schemes wean out the casualty on the lower-caste farmers becomes immediately evident. Nonetheless, the higher-caste farmers not only are in a position to reap the benefits of such programs (the adoption rate as well as impact on productivity suggest this), but could take that forward even after the schemes pull out of the scene. Not only poor resource ownership and endowment but the fear of losing their rights to reuse seeds might be working against speedy adoption of improved practices.

As expected, farmers who are better educated have greater ability to process information and search for technologies suitable to their production constraints than those who are less educated. The low positive coefficient for secondary occupation and affiliation to the local institutions tell a different tale altogether. It seems availability of non-farm occupation opportunity has not generated enough income for the household to innovate. The poor state of local institutions also has negative impact on the innovation behavior.

Thus, there is a need to strengthen local institutions and create local non-farm employment opportunities that would enhance not only the kitty of the households, but they could avail the surplus income to invest in their on-farm activities and generate further income to create a sustainable livelihood model. This is truer for the sub-marginal farmers.

Conclusions

This study throws some interesting facts through which critical inferences could be drawn not only for the study area or the state of Bihar but for a large part of India and the subcontinent. It suggests and we may conclude that social stratifications have a direct bearing on the agrarian progress. The sample study backs this conclusion with statistically significant coefficient for caste apart from the crude observations made such as, the lower-caste farmers are perennially marginalized in terms of owning land (less than an acre) with quite extremely poor resource ownership and/or endowment. At least for most of Bihar, quality of education and supporting institutions does not seem to improve the small farmer's condition.

As the on-farm employment and income recedes, the role of non-farm employment becomes critical. In such situation, with lack of non-farm employment and income at the local level forces (in fact have already forced) many a farmer migrates to near-far suburban or urban centers. This is detrimental to the small-farming activities in general as well as food security in particular. Recent studies [4] have indicated that even at pan-India level small holdings below 0.8 ha do not generate enough income to keep a farm family out of poverty despite good productivity, and thus, non-farm income at local level itself becomes important for this group.

The role of local institutions is important, but if they are resource poor and inadequately positioned in terms of knowledge and power, their remaining becomes meaningless for the localities. It is critical therefore to see how the local institutions in general and agrarian institutions in particular could be strengthened, including the private service providers at the remote localities. Identification of resource poor farmers and designing appropriate and implementable agrarian policies with strong monitoring and evaluation strategies is suggested by this study to accelerate the process of adoption of innovative rice technologies to maximize the farmers' income.

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