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Impact of Bio-growth Enhancer Adoption on Input Use and Profitability in Salt-affected Smallholder Farms

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Abstract

The profitability of crop production system in India is being encountered with problems of increasing input cost, diminishing marginal returns and negative impact on ecological balance due to indiscriminate use of toxic plant protection chemicals. To overcome these problems, a cost-effective bio-growth enhancer, CSR-BIO was developed under National Agricultural Innovation Project and intervened in the salt-affected smallholder farms of Uttar Pradesh, India. The current study assessed the impact of CSR-BIO adoption on input use and profitability in salt-affected smallholder farms. Results showed an increase in yield in the adopter farms ranged from 13.64% in banana to 21.88% in red gram. The net profit was also higher in adopter farms compared to non-adopter farms in all the crops. The use of CSR-BIO also reduced number of plant protection chemical sprays in adopter farms. Logistic regression model was used to know the behavior of farmers in the adoption of CSR-BIO. The results indicated that farm size and contact with extension agency were positive and significant. It was observed that non-availability at the time of requirement and not available in adequate quantity were the major constraints faced by the farmers. Study suggested that CSR-BIO can be made available to the farmers through agro-input retailers for wider adoption.

Key words: Alkali soils, Bio-growth enhancer, CSR-BIO technology, Logistic regression

Introduction

The use of fertilizers and plant protection chemicals has made substantial contributions towards increasing crop productivity in India (FAO, 2005). But in recent years, they have come under severe criticism because of their negative externalities. The use of toxic plant protection chemicals has resulted in serious health implications to man and his environment (Wasim *et al.,* 2009). Biological alternatives have been proposed since long, and are claimed to provide effective solutions to the pest and disease problems. However, their utility has been limited due to a number of technological, socio-economic and institutional constraints. Nevertheless, with rising public awareness of the harmful effect of agro-chemicals and demand for chemical-free organic foods made the biological pest management an important alternative for developing plant protection strategies.

Future projections on food security, suggested production of more food and fibre will be needed to meet the expanding demand of the growing world population and that could be achieved only by bringing salt-affected and waste lands into cultivation (Bouwer, 2000). Chemical amendments being used in reclamation process, ameliorated top 0-15 cm soil leaving the physical properties like congestion of water and nutrients in rhizosphere soil unchanged. The research efforts on introducing income driven horticultural crops in the reclaimed sodic soils using rhizosphere diversity gave higher crop yield (Damodaran *et al.,* 2013a). ICAR-Central Soil Salinity Research Institute under a strategic research project funded by National Agricultural Innovation Project of Indian Council of Agricultural Research with the support of World Bank developed a bio-product, CSR-BIO using consortia of salt tolerant bacteria on a patent protected media for enhancing the growth and yield potential of the agri-horticultural crops under salt stressed environment (Damodaran *et al.,* 2015). This technology was intervened in salt-

affected farms in Uttar Pradesh, India through training and demonstration.

The bio-growth enhancer acts as a nutrient mobilizer, soil vitalizer, protects against soil borne diseases and growth enhancer for crops grown in normal and alkali soils (Damodaran *et al.,* 2013b). The technology was developed and commercialized for supply to the farmers through licensed producers.

Economic viability and sustainability are considered essential for success of new technology. Since the adoption of this innovative technology in fruits, vegetables and other crops was found to be high and at the same time, limited studies on economic performance of CSR-BIO technology have been carried out to evaluate its impact on input use and farm profitability. Current study has been formulated to assess the impact of bio-growth enhancer, CSR-BIO on chemical input use and profitability of crops in salt-affected smallholder farms.

Materials and Methods

The study was based on primary survey on farm households conducted during 2015-16 to 2016-17 in Trivediganj block of Barabanki district and Gauriganj block of Amethi district in Uttar Pradesh as CSR-BIO technology had been demonstrated in these blocks during 2010-11 to 2012-13. A total of 60 CSR-BIO adopters and equal number of non-adopter farmers were selected at random from each block. Thus, the total sample size for the study constituted 120 adopters and 120 non-adopters of CSR-BIO technology. The information on socio-economic conditions, input use, costs and returns were collected by the survey method using a specially designed interview questionnaire. The costs and returns have been estimated based on 2016-17 prices. The cost included all direct expenses paid in cash and kind for crop production such as hired human labour, machine labour, seeds, fertilizers, irrigation, plant protection measures, overhead charges and imputed value of family labour. The overhead charges include the land revenue paid to the state government, charges paid for repairs, maintenance and depreciation of fixed assets, interest on working capital and fixed capital. Gross income comprises the total value of main product and by-products. Net income was calculated by taking the difference between gross income and cost of cultivation.

Logistic regression model

As the 'adoption of CSR-BIO technology' is a binary dependent variable, with the option of either 'adoption' or 'non-adoption', Logistic Regression was considered to be the most appropriate analytical tool to find out the factors determining the adoption. This study has assumed that the probability of a farmer adopting CSR-BIO technology depends on the independent variables like age of the farmer in years (X_1), literacy level in completed years of schooling (X_2), farm size in hectare (X_3) and number of times contacts with extension agencies in a year (X_4). The Logistic Regression model has been estimated by the equation (1):

$$Y = \frac{e^{\beta_0} + \beta_i X_i + \ldots + \beta_n X_n}{1 + e^{\beta_0} + \beta_i X_i + \ldots + \beta_n X_n} \qquad \ldots(1)$$

Rearranging equation (1) and taking natural log on both sides, equation (2) can be derived. The coefficients are estimated using the maximum likelihood method (Peng *et al.,* 2002).

$$\ln\left[\frac{Y_i}{1-Y_i}\right] = \beta_0 + \beta_i X_i + \ldots + \beta_n X_n \qquad \ldots(2)$$

where,

Y_i = Probability that the i^{th} farmer is an adopter of CSR-BIO

$(1-Y_i)$ = Probability that the i^{th} farmer is a non-adopter of CSR-BIO

X_i = Independent variables (i = 1 to 4)

β_0 = Intercept

β_i = Logit coefficients (i = 1 to 4)

Results and Discussion

The average farm size was 1.56 ha and a majority of the farmers (73%) belong to marginal and small farmer category (Table 1). The crop production was the most important activity contributing 89% to the total household income. A few farmers (8%)

Table 1. Socio-economic profile of farmers

Particulars	Figures
General information	
Age (years)	47
Literacy level (%)	74
Family size (No.)	7
Average farm size (ha)	1.56
Soil pH	8.2-9.4
Classification of farm holdings (%)	
Marginal (<1 ha)	29
Small (1 - 2 ha)	44
Medium (2 - 10 ha)	25
Large (> 10 ha)	2
Sources of family income (%)	
Crop production	89
Livestock	3
Services	1
Business	2
Other sources	5

Source: Primary survey by authors

supplemented their household income by engaging themselves or their family members in off-farm activities. Farmers grow crops in *kharif* season (June–October) and *rabi* seasons (November–March). Transplanted paddy (*Oryza sativa*) is the most popular *kharif* season crop. Wheat (*Triticum aestivum*) is grown after rice in the *rabi* season. Farmers also grow fruits, vegetables and flowers in a small portion of their land. Soils are slight to moderately sodic in nature as soil PH ranged from 8.2 to 9.4. The crop productivity is much lower in sodic soils than the normal soils.

Success or failure of any technology is mainly attributed to its economic profitability (Canavari *et al.,* 2007). The technology that sustains the economic profitability will change the poverty status of the region if backed with strong eco-friendly scientific principle (Nemes, 2009). Based on the primary survey data, the impact of CSR-BIO was assessed in terms of yield, cost and returns. The analysis revealed a positive economic impact of adoption of CSR-BIO on different crops. The yield was higher across the crops in CSR-BIO adopted farms than non-adopter farms (Table 2).

The yield increase was highest in red gram. The yield gain was 400 kg ha^{-1} indicating 21.88% higher yield due to use of CSR-BIO. The yield increase was also observed in potato (17.61%), wheat (14.63%), tomato (14.29%) and banana (13.64%). The yield gain may also be attributed to the reduced soil borne disease incidence in the CSR-BIO applied fields as compared to the non-adopter's fields. The microbial strains used in the CSR-BIO was also reported to have antagonistic properties against the soil borne diseases like wilt caused by *Fusarium solani* (Damodaran *et al.,* 2013c). CSR-BIO, a bio-product based on consortia of effective microbes facilitated the uptake of potassium, ferrous and calcium in bio-primed vegetables resulting in higher growth and yield (Damodaran *et al.,* 2014). Adopters observed that the use of CSR-BIO had imparted luster to banana and tomato, hence improved produce appearance. They received higher prices for banana (10%) and tomato (6.25%).

The profit per ha was ₹ 480 in non-adopter farms and ₹ 8447 in adopter farms, indicating remarkable net profit gain due to use of CSR-BIO (Table 3). The net profit gain was also higher in potato followed by banana, wheat, tomato and

Table 2. Changes in crop yield and per unit price of crop produce

Crop	Yield (Mg ha^{-1})			Price per unit (₹ Mg^{-1})		
	Non-adopters	Adopters	Change (%)	Non-adopters	Adopters	Change (%)
Banana	41	46	13.64	1000	1100	10.00
Tomato	70	80	14.29	800	850	6.25
Potato	28	33	17.61	900	900	0.00
Rice	6.0	6.8	13.33	1450	1450	0.00
Wheat	4.1	4.7	14.63	1450	1450	0.00
Red gram	1.6	2.0	21.88	3000	3000	0.00

Source: Primary survey by authors, Mg represents Mega gram or tons.

Table 3. Change in the profit due CSR-BIO use

Crop	Gross income (₹ ha^{-1})		Total cost (₹ ha^{-1})		Net return (₹ ha^{-1})		Benefit cost ratio	
	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters
Banana	594000	742500	212932	216180	381068	526320	2.79	3.43
Tomato	560000	680000	222969	222809	337031	457190	2.51	3.05
Potato	255600	300600	185258	190346	70342	110254	1.38	1.58
Rice	105000	119000	70631	73387	34369	45613	1.49	1.62
Wheat	71750	82250	56624	61415	15126	20835	1.27	1.34
Red gram	48000	58500	47520	50053	480	8447	1.01	1.17

Source: Primary survey by authors

rice. The higher profits in crop production were due to yield increase, decrease in disease incidence and input cost reduction. The benefit cost ratios were higher in adopter farms than non-adopter farms in all the crops.

The impact of adoption of CSR-BIO was assessed in terms of reduction in the use of chemical fertilizers and plant protection chemicals. CSR-BIO adopted farmers have saved 100 kg ha^{-1} Di-Ammonium Phosphate (DAP) fertilizer in banana and saved 21.16% fertilizer expenditure. They have also saved 50 kg ha^{-1} DAP fertilizer in rice which resulted in 11.28% reduction in fertilizer expenditure (Table 4).

The use of CSR-BIO also reduced number of plant protection chemical sprays from 13 sprays to 8 sprays in banana. In other crops, farmers on an average saved 3 sprays. Hence, reduction in the sprays brought down the cost of plant protection chemicals by 31% in red gram followed by 27.16% in potato, 8.81% in tomato and 8.59% in banana. The reduction in the use of plant protection chemicals was due to the bio-control potential of the microbial consortia in the soil and foliar parts of the respective crops. Use of *Trichoderma harzsianum* as a biocontrol agent reduces the use of fungicide (Sharma, 2011; John *et al.,* 2010). Technologies reducing the use of chemical insecticides and fungicides protects the environment from the toxic chemicals thereby reducing the risk of dreadful disease like cancer and diseases relating to central nervous system failure (Coat *et al.,* 2006). The CSR-BIO technology had attributed in saving of expenditure incurred in crop production and simultaneously it has also helped in protecting the environment and the end users from residual toxicity effects of the chemicals. The reduction in the plant protection chemicals spray helped in harbouring more predators' population in the eco-system (Damodaran *et al.,* 2013a).

Results of the parameter estimation using Logistic Regression model are shown in the Table 5. It was observed that farm size and contact with extension agency were positive and significant. In the logistic regression, the change of a dependent variable due to a unit change of an independent variable can be estimated using odds ratios. Hence,

Table 4. Impact of CSR-BIO application on crop input use

Crop	Fertilizer cost (₹ ha^{-1})			Plant protection chemicals cost (₹ ha^{-1})		
	Non-adopters	Adopters	Change (%)	Non-adopters	Adopters	Change (%)
Banana	10917	8667	-20.61	10867	9933	-8.59
Tomato	25480	23080	-9.42	10780	9830	-8.81
Potato	32884	32884	0.00	6260	4560	-27.16
Rice	10639	9439	-11.28	1600	1600	0.00
Wheat	5260	5260	0.00	1200	1200	0.00
Red gram	7236	7236	0.00	1740	1200	-31.03

Source: Primary survey by authors

Table 5. Results of Logistic Regression parameter estimation and their statistics

Variables	β	SE β	Wald's χ^2	df	Significance (p=0.05)	e^{β} (odds ratio)
Farm size	2.031*	1.021	3.957	1	0.047	7.624
Education	0.251	0.979	0.066	1	0.797	1.286
Contact with extension agency	8.238*	2.808	8.611	1	0.003	0.0004
Age	-0.058	.091	0.406	1	0.524	0.944
Constant	-6.589	3.758	3.073	1	0.080	NA

Note: Nagelkerke R^2 = 0.76, Cox and Snell R^2 = 0.57; NA = Not Applicable; *Statistically significant at 95% confidence level
Source: Computed by authors using SPSS 16.0

it can be inferred that the odds of adopting CSR-BIO is 0.0004 times higher for the farmer who has in contact with extension agencies. Similarly, the model predicted that a unit increase in farm size increases the odds of CSR-BIO adoption by 7.624 times. The extension person's interactions with farmers would help in rapid adoption of CSR-BIO. Small, medium and large size land holding farmers have showed interest in attending training and demonstration programmes as well as adopting the technology intensively than the marginal farmers.

Adopters agreed that CSR-BIO has increased yield and lowered the occurrence of fungal diseases (Table 6). About 92% farmers opined that crops would become green and healthy. Majority of farmers (96%) noticed that use of CSR-BIO effectively prevented fungal diseases in crops. Banana and rice required less fertilizer due to good crop health as observed by 64% farmers. Nearly half of the farmers have observed that the keeping quality of fruits and vegetables would increase. The use of CSR-BIO had improved appearance for the produce as it imparted luster to it. Many farmers (92%) opined that the crop output fetched higher market prices due to improvement in product quality in terms of shininess and keeping quality.

The use of CSR-BIO formulation is economically profitable as returns are higher on adopter farms than non-adopter farms. Farmers are willing to substitute the plant protection chemicals and growth promoters with CSR-BIO. They knew the usefulness of cost effective, eco-friendly bio-growth enhancer for sustainable crop production. However, farmers encountered a number of problems in switching over from the chemical control to CSR-BIO (Table 7).

Table 6. Opinion of the farmers on the advantages of using CSR-BIO

Sl no.	Advantages	Opinion (%)
1	Yield enhancement	100
2	Effective control of fungal diseases	96
3	Green and healthy crops	92
4	Crops require less fertilizer	64
5	Crops require less PPC	96
6	Gives brightness to the fruits	72
7	Commands higher prices in the market	92
8	Good keeping quality	48

Source: Primary survey by authors

Table 7. Opinion of the farmers on constraints faced by them

Constraints	Opinion (%)
Not available	38
Available, but not on time	57
Inadequate availability	72
Uncertainty of availability	47

Source: Primary survey by authors

Majority of the farmers (72%) opined that inadequate availability of CSR-BIO. Non-availability of CSR-BIO is another constraint faced by 38% farmers. Nearly half of the farmers opined that even if it is available, the required quantity of CSR-BIO availability is uncertain. Adequate and timely supply of CSR-BIO and lack of timely expert advice were main impediments. These constraints are mainly due to a limited licensed CSR-BIO producer and not available in the local agro-input stores. The product needs to

be popularized by making available through local agro-input retailers for wider adoption to improve crop yield and reduce the use of harmful plant protection chemicals.

Conclusions

CSR-BIO technology is economically feasible and helps in augmenting farm income. CSR-BIO technology showed scope for increasing crop yield, reduction in plant protection chemicals and fertilizer use. It also has a favorable impact on product prices due to improvement in product quality. The non-availability at the time of requirement and not available in adequate quantity were the major constraints faced by the farmers. The technology need to be popularised by improving the availability in the local market through the agro-input retailers for wider adoption.

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