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ARTICLE

Moving Towards Sustainable Production through Access to Extension Services: Evidence from Rice Growing States

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ABSTRACT

The optimal fertiliser must be applied at the appropriate dosage to achieve maximum yield benefits. However, haphazard fertiliser application frequently leads to diminished crop responses. The study has tested this in rice using plot-level panel data for three years for the leading rice-growing states of the country by applying a quadratic yield response function with customised specifications. Wide variation in yield response to fertiliser use existed among the states, and the response was lower in states where a greater proportion of farmers overused nitrogen. Considering the importance of conjunctive use of chemical and organic fertilisers for a sustainable future, we analyse the farmers' expenditure on fertilisers using data from 400 rice farmers of Indo-Gangetic Plains. Specifically, we tested the effect of farmers' access to Public Agricultural Extension Services on their fertiliser expenditure using Inverse Probability Weighted Regression Adjustment. The farmers with access to Public Agricultural Extension Services spent significantly higher on organic fertilisers than those without access. The results suggest that the Public Agricultural Extension System can be trusted as an effective medium for achieving the targets of enhanced organic fertiliser use in the region.

Keywords: Fertiliser Use, Crop response, Agricultural extension, Inverse Probability Weighted Regression, Rice production

JEL.: Q01, Q12, Q18, Q56,

I

INTRODUCTION

The task of bettering the crop yields is a continuous process and in view of increasing population pressure and decreasing resource availability for farming, achieving better use efficiencies in fertilisers is a must (Hossain and Singh, 2000). The question that the policymakers face is whether increasing fertiliser use is enough in the future? There increasing worry regarding the sustainability of a rising trend in fertiliser use in several parts of India (Patra *et al.,* 2016). Currently, excessive chemical fertilisers are being applied to our crops in several regions (Kishore *et al*., 2013), which ultimately causes pollution to our ecosphere and brings down crop response. Thus, while fertiliser consumption continued to rise substantially in India, the output elasticity of fertilisers dropped sharply (Kapur, 2011). The crop response also varies spatially with the changing agro-ecological conditions. Thus, this study dealt with an analysis of spatial variation in yield response of major crops to fertilisers.

Also, in the wake of mounting costs of chemical fertiliser application and the changing perceptions in favour of the environment, there is a need to revisit the current soil fertilisation strategies and work for a judicious mix of chemical and organic technologies for greater sustainability of agriculture in the country (Ghosh, 2004).

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Additionally, the Indian government has increasingly stressed this by implementing programmes such as National Project on Organic Farming, Paramparagat Krishi Vikas Yojana, Rashtriya Krishi Vikas Yojana, National Mission for Sustainable Agriculture, and National Program for Organic Production that encourages the use of organic fertiliser in farming. Even though the advantages of utilising organic fertilisers are well known, India still has a low rate of farm adoption (Panneerselvam *et al.,* 2010). Farmers' irrational use of fertilisers can be attributed to their limited access to scientific and technical information. The access to agricultural extension services gains relevance against this backdrop.

Given the importance of achieving a conjunctive use of chemical and organic fertilisers for a sustainable future, deciphering the effect of access to Public Agricultural Extension Services (PAES) on fertiliser expenditure by farmers would provide newer insights for policymakers. Access to extension services has had a positive effect on the adoption of organic fertilisers as reported by Emmanuel *et al.,* (2016). Agricultural extension services significantly boost farmers' organic fertiliser use in China and ecological cognition partly mediates this effect (Qiao *et al*., 2022). In addition, access to extension system may have an effect of reducing the use of chemical fertilisers as well (Rahman and Connor, 2022). Many studies have looked into the factors that influence organic fertiliser adoption, but very few have explicitly dealt with the effect of access to PAES on organic fertiliser adoption. Most importantly, adoption decisions and the level (expenditure) of the use of organic fertilisers are sequential decisions. Appropriate econometric techniques are required for the estimation of the factors impacting them, in which the earlier studies were lacking. To close this knowledge gap, we conduct an extensive rural household survey in the Indo-Gangetic plains and utilise the data to empirically assess the effect of access to PAES on fertiliser expenditure, both chemical and organic. Farmers cultivating rice are included in this study, as the rice-wheat farming system is most prevalent in the area. Since the green revolution, farmers in the area have used input-intensive farming techniques, making this a good example to examine, and hence it is an excellent case to study their perception and preferences towards organic fertilisers.

II

DATA AND METHODOLOGY

Yield Response of Rice to Nitrogen Fertilisers

We created a three-year panel from the cost of cultivation data released by the Directorate of Economics and Statistics, Government of India, to analyse rice yield response. An identification variable for each observation in the cost of cultivation data was created first by merging the zone number, tehsil number, cultivator number, and the parcel plot season. Using this identification variable, we created panel data by including only those observations that were repeated for all the years (2014-15, 2015-16, and 2016-17). Separate panel data was created for leading states producing rice.

Most recent studies on the analysis of yield response to fertiliser apply variations on quadratic models. Our functional form includes the quadratic term for nitrogen, and we specify interactions of nitrogen use with time, rainfall, manure use, etc. Yield (Y) on plot i from household j in time t is a function of:

$$Yijt = \alpha_0 + \alpha_1 N_{ijt} + \alpha_2 AEC_{ijt} + \alpha_3 X_{ijt} + \beta_1 N^2_{ijt} + \beta_2 N_{ijt} * rainfall_{ijt} + \beta_3 N_{ijt} * manure_{ijt} + U_{ijt}$$

Where

N_{ijt} is the fertiliser application rate (primarily nitrogen fertiliser)
AEC_{ijt} is the agro-ecological conditions
X_{ijt} is a vector of other covariates
α and β represent the parameter estimates
U_{ijt} is the error term

The coefficient of the variable nitrogen in the production function is the crop response to nitrogen fertilisers, which means that the value of the coefficient indicates the percent change in crop yield due to a unit increase in the nitrogen input. After estimating the yield response, we then calculate the Marginal Physical Product (MPP) and the Marginal Value Product (MVP) using the coefficient estimates of the yield function and the unit price of the output. We then equate the MVP with the input price (the price of nitrogen) to calculate the per cent of farmers overusing nitrogen in rice cultivation. If a farmer's MVP is less than the unit price of nitrogen, that farmer overuse nitrogen, and to reach the position of maximum profitability, he should reduce nitrogen use.

Impact of Access to Extension Services

We test the impact of access to PAES on fertiliser expenditure using data collected from 400 rice farmers of the IGP, India, from March to June 2020. We used a multi-stage sampling technique to collect the primary data from the IGP. In the first stage, we randomly selected Karnal from Upper Gangetic Plains and Gorakhpur from the Middle Gangetic plains among the region's districts. These districts fall under different transect zones of IGP and have varying levels of agrarian dynamism. In the second stage, we selected one block from each district (Karnal block from Karnal district and Bansgaon block from Gorakhpur district) based on the maximum area under rice cultivation, as per the information provided by the District Agricultural Department of Karnal and Krishi Vigyan Kendra of Gorakhpur. We randomly selected four villages (Kalampura, Kachhwa, Sangohi, and Landhora from the Karnal block; Basauli, Dhobauli, Siswan, and Bharohia from the Bansgaon block). In the final stage, 50 farmers were selected randomly from each of the eight selected villages, which enabled us to survey the farmers and collect data from a total of 400 rice farmers, of which only 32 per cent of farmers adopted organic fertilisers.

Out of the 400 farmers surveyed from the study area, only 69 farmers (17.25 per cent) had access to public agricultural extension services. Access to PAES cannot be considered an exogenous variable since several socio-economic factors may determine it. Hence it is necessary to address this endogeneity issue when we estimate the impact of access to PAES on fertiliser expenditure. We use the treatment effects model to address the endogeneity issue arising from both observed and unobserved factors (Lin *et al*., 2022). Specifically, we use the Inverse Probability Weighted

Regression Adjustment (IPWRA). IPWRA helps model both the outcomes and the treatment to control for the endogeneity in accessing information from PAES. This model is “doubly robust” and allows us to obtain consistent estimators on fertiliser expenditure.

III

RESULTS AND DISCUSSION

Spatial Variation in Rice Yield Response to Fertilisers

Yield response from applied chemical fertilisers or nutrients is a topic studied by several researchers based on experimental plot data; however, no studies have utilised the farmers’ plot-level panel data of leading states growing rice in India. The crop response from experimental fields may vary significantly from that of the farmers’ fields; hence using farmers’ data yields results of better utility. Such an approach using panel data will also help us to filter out the issues arising with some of the omitted variables like socio-economic variables of the farmers, which are not available with plot level cost of cultivation data provided by the Directorate of Economics and Statistics, Government of India.

The results of yield function estimates are given in Table 1. The nitrogen terms generate positive and significant estimates for all the states considered, indicating that the rice yield response is positive in most states. Similarly, the squared terms of nitrogen generated negative and significant estimates in some states suggesting the prevalence of a diminishing marginal returns relationship there. The agro-ecological zones and the rainfall and temperature variables significantly affected crop yield. Irrigation, high-yielding varieties, and crop area are other significant variables affecting crop yields. In the case of rice, the highest yield response per kg nitrogen was observed in Odisha, followed by the states Madhya Pradesh, Haryana, West Bengal, and Punjab. In the case of wheat, Madhya Pradesh, Uttarakhand, Maharashtra, Bihar, and Uttar Pradesh are the states with the highest yield response.

Our estimation of the overuse of nitrogen is given in Figure 1. While 78 per cent of farmers from Punjab considered in our analysis overused nitrogen, the values were 74, 72, and 68 per cent, respectively, in the states of Haryana, Uttar Pradesh, and Andhra Pradesh. While the overuse of nitrogen was observed in 21 per cent of farmers in the states of Odisha and West Bengal, it was practiced by 45 per cent of rice farmers of Madhya Pradesh. However, our findings must be interpreted with caution as it is entirely based on the farmers’ data covered in the plot level cost of cultivation data. Further, we do not attempt to generalise our findings to the entire state by applying weights. Still, it has indicated the trend in the overuse of nitrogen fertilisers in rice cultivation in different states.

TABLE 1. RICE YIELD FUNCTION ESTIMATES

Parameters (1)	Andhra Pradesh (2)	Haryana (3)	Madhya Pradesh (4)	Odisha (5)	Punjab (6)	Tamil Nadu (7)	Uttar Pradesh (8)	West Bengal (9)
Nitrogen (kg)	0.023***	0.123***	0.167**	0.304***	0.099***	0.017*	0.042*	0.111***
(SE)	-0.008	-0.025	-0.083	-0.025	-0.034	-0.009	-0.025	-0.015
Time (years)			3.532**	0.676**	0.223		0.606	0.939***
(SE)			-1.525	-0.331	-1.353		-0.567	-0.269
Nitrogen*Time			-0.024	0.025***	-0.01		0.001	-0.013***
(SE)			-0.019	-0.005	-0.009		-0.005	-0.003
Nitrogen squared	-0.001	-0.001	-0.001***	-0.002***	0	-0.001	-0.001	-0.001***
(SE)	0.001	0.001	0	0	0	0.001	0.001	0.001
Nitrogen*Manure	0.001	0.001	0.001	0.001*	0.001**	0.001	0.001	0.001
(SE)	0.001	-0.001	0.001	0.001	0.001	0.001	0.001	0.001
Rainfall (mm)	0.001	0.025***	0.001	0.001	-0.001***	0.002**	0.001	0.001
(SE)	-0.001	-0.008	0.001	0.001	0.001	-0.001	0.001	0.001
Nitrogen*Rainfall			0.001***	0.001	0.001	0.001	-0.001***	0.001**
(SE)			0.001	0.001	0.001	0.001	0.001	0.001
Maximum temperature (^{0}**C)**	-3.329***	10.783***	7.055***	-2.003***	-5.287***	4.908***	5.284***	-0.656***
(SE)	-0.411	-3.381	-2.446	-0.46	-0.82	-0.963	-0.415	-0.163
Minimum temperature (^{0}**C)**	5.025***	-15.267***	-14.440***	-1.850***	9.915***	-6.938***	-8.815***	0.943***
(SE)	-0.601	-4.964	-2.002	-0.195	-1.533	-0.803	-0.66	-0.247
Human labour (Rupees)	-0.002	-0.037***	0.001**	0.001***	0.001	0.001***	0.001***	0.001***
(SE)	-0.002	-0.006	0.001	0.001	0.001	0.001	0.001	0.001
Animal labour (Rupees)	-0.031**	0.067	-0.001**	-0.001***	0.006**	-0.001*	0.001	-0.001***
(SE)	-0.015	-0.745	0.001	0.001	-0.002	0.001	0.001	0.001
Machine labour (Rupees)	0.001	0.001	0.001	0.001***	0.001	0.001***	0.001***	0.001***
(SE)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Seed (Rupees)	0.001**	0.001	0.001***	0.001***	-0.002**	0.001***	0.001***	0.001***
(SE)	-0.001	-0.001	0.001	0.001	-0.001	0.001	0.001	0.001
Phosphorous (kg)		0.033	-0.016	0.006	-0.025*	-0.024*	-0.01	0.066***
(SE)		-0.04	-0.023	-0.009	-0.014	-0.014	-0.009	-0.007
Potash (kg)	0.047***	-0.026	-0.028	0.104***	0.036		0.001	-0.021***
(SE)	-0.011	-0.107	-0.036	-0.007	-0.029		-0.037	-0.005
Insecticide (Rs)	0.001*	0.001***	0.001***	0.001***	0.000**	0.001***	0.001*	0.001***
(SE)	0.001	-0.001	0.001	0.001	0.001	0	0.001	0.001
Irrigation (Rs	-0.001*	0.001	0.001	0.001***	0.001	0.001**	-0.001***	0.001***
(SE)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Crop area (ha)	1.210***		-0.395	1.997***	0.633**		1.004**	-5.188***
(SE)	-0.404		-0.824	-0.312	-0.285		-0.503	-0.765
Agro-ecological zone dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
High yielding variety	-21.400**		21.916***	6.495***	-9.584		8.971***	3.599
(SE)	-10.125		-1.823	-0.641	-7.617		-3.058	-4.495
Constant	50.821***	-25.774	51.49	110.734***	65.500***	56.531**	24.720***	29.779***
(SE)	-4.655	-35.088	-65.492	-17.404	-8.462	-24.651	-4.27	-4.627
Observations	1134	237	462	4767	828	1038	1302	6282
Number of farmers	378	79	154	1589	276	346	434	2095

***,**,* indicates significance at 1, 5 and 10 per cent levels respectively.

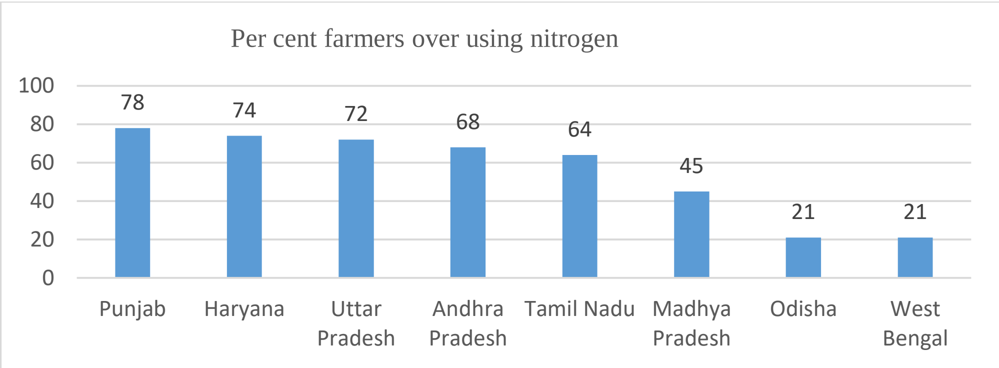

Figure 1. Overuse of Nitrogen Fertilisers in Rice Cultivation

Though crop response to fertilisers is a topic widely covered in agronomic literature, we innovate by utilising the plot level cost of cultivation data. The novelty is that we created a three-year panel from the plot level cost of cultivation data, and to our knowledge, this is the first of such attempts to find out the spatial variation in rice response to nitrogen fertiliser in India. Our analysis suggested that the crop response has decreased considerably in the green revolution states of Punjab and Haryana, and we also report that the per cent of farmers overusing nitrogen in these states is comparatively higher. A similar pattern was also observed in another state from the Indo-Gangetic Plains; Uttar Pradesh. Our findings imply that it is high time to find ways to align the fertiliser application with the nutrient requirement of the soil. Similar result indicating the relationship between high nitrogen fertiliser use and lower crop response was reported internationally by Hossain and Singh, 2000.

Farmers' Perception of Chemical Fertilisers

Next, we present the farmers' perception of chemical fertilisers based on the data collected on a five-point Likert scale (Figure 2). This information will help us understand whether farmers understand the possible environmental and human externalities of chemical fertiliser overuse. The figure plots the per cent of farmers agreeing and disagreeing with the different questions on their perception of chemical fertiliser use. Most farmers felt that chemical fertilisers are not very harmful to soil, water bodies, and agricultural produce. However, they felt that chemical fertilisers are harmful to humans. Only one per cent of farmers opined that chemical fertilisers do not have any adverse effects, suggesting that the farmers, in general, are ready to acknowledge the adverse effects of chemical fertilisers but are not ready to accept the same in response to questions specific to the soil, water and agricultural produce. Since our study area is a traditionally high chemical fertiliser consuming region, the general responses also support such a fertiliser application behaviour. However, if we need to promote sustainable technologies like organic fertilisers, educating the farmers on the externalities of overuse of chemical fertilisers is crucial.

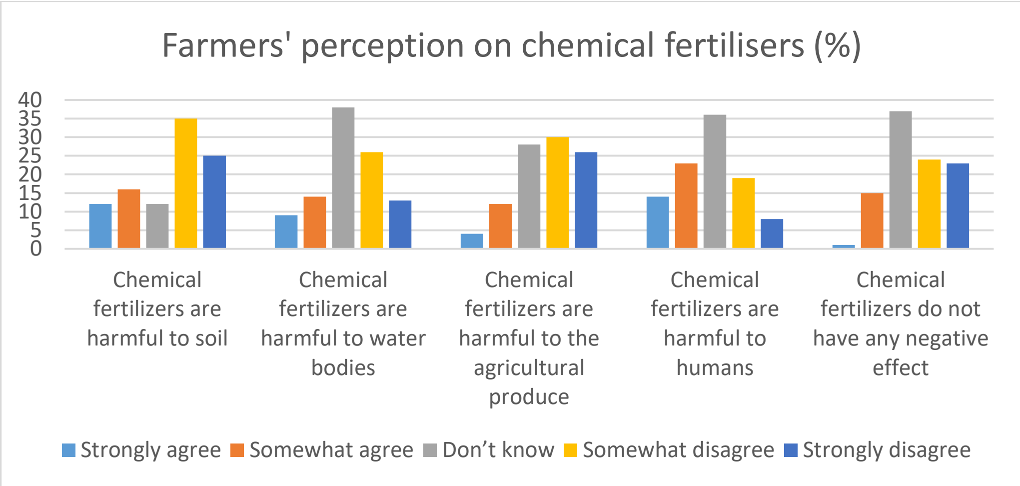

Figure 2. Farmers' Perception on the Effect of Chemical Fertilisers

Effect of Access to Public Agricultural Extension Agencies on Fertiliser Expenditure

The farmers with access to PAES and their counterparts differed significantly in several socio-economic variables (Table 2). While the average expenditure on chemical and organic fertilisers was Rs. 4205 and Rs. 396 respectively for the farmers without access to PAES, it was Rs. 4414 and Rs. 1054 respectively for the farmers having access to PAES. The estimation results of the IPWRA with chemical fertiliser and organic fertiliser as the dependent variables are given in Table 3. It is clear from the table that the access to PAES did not affect the farmers' average chemical fertiliser expenditure, but it significantly affected the organic fertiliser expenditure. Precisely, access to PAES increased the expenditure on organic fertilisers by an average of Rs 698.29 per ha. Our finding has policy significance since the government also target to improve the use of organic fertiliser expenditure. It calls for further strengthening the PAES so that it can effectively act to bring change in terms of reducing chemical fertiliser expenditure as well. The target should be to achieve a conjunctive use of chemical and organic fertilisers. Table 3 further provides information on the variables that significantly affect the farmers' decision to access information from PAES (treatment model) and the effect of that on the expenditure for treated (outcome equation for treated) and control (outcome equation for control) groups separately.

TABLE 2. DESCRIPTIVE STATISTICS OF VARIABLES INCLUDED IN THE MODEL

Variables (1)	Farmers with no access to PAES (2)	Farmers with access to PAES (3)	Mean difference (4)
Chemical fertiliser expenditure (Rs/ha)	4205.533	4414.596	-209.063
Organic fertiliser expenditure (Rs/ha)	396.473	1054.823	-1.0e+03***
Gender	0.955	0.971	-0.016
Age	49.208	42.232	6.977***
Disadvantaged section	0.103	0.058	0.045
Education	7.329	10.304	-2.975***
Farming experience	30.761	23.855	6.906***
Tenure security	0.254	0.13	0.123**
Soil health card	0.459	0.768	-0.309***
Membership	0.163	0.754	-0.590***
Distance to the farm	0.459	0.768	-0.309***
Asset	0.163	0.754	-0.590***
Risk score	0.785	0.783	0.003
Soil fertility	3.858	3.812	0.046
Farmers' perceptions towards organic fertilisers (5-point scale: 1 = strongly agree; 5 = strongly disagree)			
Reduce yield	2.909	3.899	-0.989***
Better output price	2.592	2.217	0.375***
Increases pest and disease attack	2.915	3.841	-0.925***
Better acceptance in the market	2.746	2.116	0.630***
Farmers' perceptions towards policy variables for promoting organic fertilisers (5-point scale: 1 = strongly agree; 5 = strongly disagree)			
Output sale contract	2.562	2.942	-0.380***
Farm certification	2.224	3.246	-1.023***
Subsidy	1.789	4.072	-2.284***

TABLE 3. EFFECT OF ACCESS TO PAES ON FERTILISER EXPENDITURE

Parameters	Chemical fertiliser		Organic fertiliser	
	Coefficients	Std. Err.	Coefficients	Std. Err.
(1)	(2)	(3)	(4)	(5)
Average Treatment Effect of the access to PAES on fertiliser expenditure	-145.47	177.1	698.29***	268.0721
Potential mean outcome of control group	4260.72***	83.47	689.45***	81.45702
Outcome equation for control				
Gender	654.47**	352.74	33	169.47
Age	2.48	8.26	-2.55	3.52
Disadvantaged section	283	310.53	109.52	107.61
Education	-11.49	21.95	16.96	11.03
Farming experience	-18.84***	7.52	2.06	2.96
Tenancy	460.27**	170.28	-176.33**	93.77
Soil Health Card	727.68***	151.71	-11.42	79.18
Membership in farm organizations	109.79	222.82	395.75***	144.51
Area			311.03***	47.54
Soil fertility	26.04	92.97	36.63	65.16
Reduce yield			124.30***	43.88
Better output price			-68.64	44.24
Increase pest and disease attack			68.75	50.86
Better market acceptance			-53.83	51.37
Output sale contract			-44.57	46.65
Farm certification			25.27	47.04
Subsidy			481.74***	63.06
Constant	3526.00***	621.11	-1020.96**	439.44
Outcome equation model for treated				
Gender	1091.14***	332.73	-323.55	260.31
Age	-2.2	15.56	8.2	5.74

Table 3 (*Contd.*)

TABLE 3 (CONCLD.)

Parameters (1)	Chemical fertiliser Coefficients (2)	Chemical fertiliser Std. Err. (3)	Organic fertiliser Coefficients (4)	Organic fertiliser Std. Err. (5)
Disadvantaged section	579.41	387.73	171.53	31.58
Education	41.37	43.9	-74.65	34.5
Farming experience	-24.04**	11.79	4.11*	1.48
Tenancy	727.76	477.44	15.26**	2.31
Soil Health Card	-304.3	335.53	224.55	37.69
Membership in farm organizations	348.31**	401.47	549.56***	377.75
Area			1012.81***	44.43
Soil fertility	-209.93	204.59	82.38	142.5
Reduce yield			-1.52***	128.22
Better output price			-236.56	98.71
Increase pest and disease attack			-113.87	142.7
Better market acceptance			263.57	163.55
Output sale contract			-166.72*	99.68
Farm certification			-12.84	98.03
Subsidy			79.20***	70.42
Constant	4209.98***	1106.4	-132.58	33.47
	Treatment model			
Gender	0.72	0.98	0.56	0.84
Age	-0.05**	0.02	-0.04*	0.01
Disadvantaged section	-0.31	0.63	-0.59	0.61
Farming experience	0.27***	0.06	-0.01**	0.01
Tenancy	-0.01	0.02	-0.82	0.38
Soil fertility	-0.66	0.4	-0.08***	0.18
Constant	-1.98	1.38	1.09	1.22

***,**,* indicates significance at 1, 5 and 10 per cent levels respectively.

IV

CONCLUSION

While fertilisers are essential for crop yield, their indiscriminate use would result in lower crop responses. We test this in this study by creating a three-year panel from the plot level cost of cultivation data to estimate a modified quadratic yield function for leading rice growing states. The results generally indicated a lower yield response in the northern states (mainly green revolution states), overusing nitrogen. The lower crop response is expected to act as a natural check to a further increase in nitrogen use in these states. The analysis of primary survey data of 400 rice farmers from the IGP region suggested that though the farmers generally acknowledge the negative effects of chemical fertilisers on humans, they do not have the same opinion when asked about soil, water, and agricultural produce. Reducing excessive use of chemical fertilisers is a pressing need to ensure environmental sustainability in the future, and agricultural extension services play a crucial role in this. We found that access to PAES would promote the expenditure on organic fertiliser while not affecting the expenditure on chemical fertilisers. Since the Government of India also target promoting organic fertilisers in the future, our findings can provide meaningful insights to the policymakers in terms of empowering the Public Agricultural Extension System. We did not include access to private extension services in our analysis since such agencies could have varying intentions and targets other than those set by the government. However, this is also a limitation of our study.

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