Does organic fertilizer adoption reduce crop revenue? Evidence from rice farmers in Indo-Gangetic Plains, India

by Praveen K.V. and Alka Singh

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Abstract

In India, Indo Gangetic Plain (IGP) is a region where the externalities of excessive use of chemical fertilizers for cereal production manifest in groundwater pollution, air pollution due to emissions, and soil degradation. In this context, we try to study the adoption of organic fertilizers and the factors determining them. We use data collected from 400 rice farmers of India's IGP region to empirically test the impact of organic fertilizer adoption on crop revenue. We use Probit and Regression Adjustment model to study the farmers' adoption of organic fertilizers and its impact on crop revenue, respectively. The results show that only 32 percent of the farmers adopted organic fertilizers in the region. Further, age, membership in farmer organizations, and education are the key variables that determine the adoption of organic fertilizers, in addition to a positive perception of the benefits of their usage. We couldn't find any significant decline in the crop revenue due to organic fertilizer adoption, which is against the popular perception of farmers. The findings highlight the importance of popularizing the right information on organic fertilizers, to form a positive perception, which will lead to better adoption.

JEL Codes: *Q150, Q160, Q180* *#19118*

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Introduction

Fertilizers are considered as a vital component for increasing the global food production and achieving food security [1]. The linkage among the global cereal production and fertilizers is widely acknowledged [2]. It is estimated that nitrogen fertilizer use (N) contributes to about 40 percent to the increases in the world's per capita food production [3]. N fertilizer's direct effect on food production has driven its global consumption growth upwards of nine times from the consumption level of the 1960s [4]. However, with increasing N consumption, more unutilized N is also released to the environment through leaching, volatilization, nitrification, and denitrification [5], since crop uptake amounts to only about 30 to 50 percent of the total fertilizers applied to soil [6]. Overuse of chemical fertilizers leads to soil and water contamination issues and greenhouse gas emissions, thus polluting the environment [7,8]. Continuous overuse of chemical fertilizers can negatively affect the soil quality and structure of the soil microbial community [9], resulting in the decline of soil organic matter and faster acidification of soil [10]. Thus, reducing the chemical fertilizer application without threatening food security to maintain agriculture sustainability is a challenge [11]. India being an agriculture-dependent nation, warrants immediate attention considering the level of fertilizer use, the use efficiency of nutrients, and the emissions and leaching that hampers the environment [12].

India is the second-largest consumer of chemical fertilizers in the world after China. India consumed about 17.6 million tonnes of N, 6.9 million tonnes of Phosphate (P), and 2.7 million tonnes of Potash (K) fertilizers in 2018 [13]. Higher fertilizer use contributed to about half of India’s grain production during the 1970s and 1980s [14]. Increased fertilizer use was

a part of the transformation of Indian agriculture through the green revolution, to which pockets like Indo-Gangetic Plains (IGP) responded favourably by the rapid adoption of the use of chemical fertilizers, High Yielding Varieties (HYVs), pesticides, machines, and irrigation [15]. Notwithstanding that such a rapid transformation has helped to feed the country's enormous population, in recent years, there is an increasing concern related to the environmental effects of indiscriminate use of fertilizers [16]. The pertinent question is how to continue increasing food production without disturbing the environment [6].

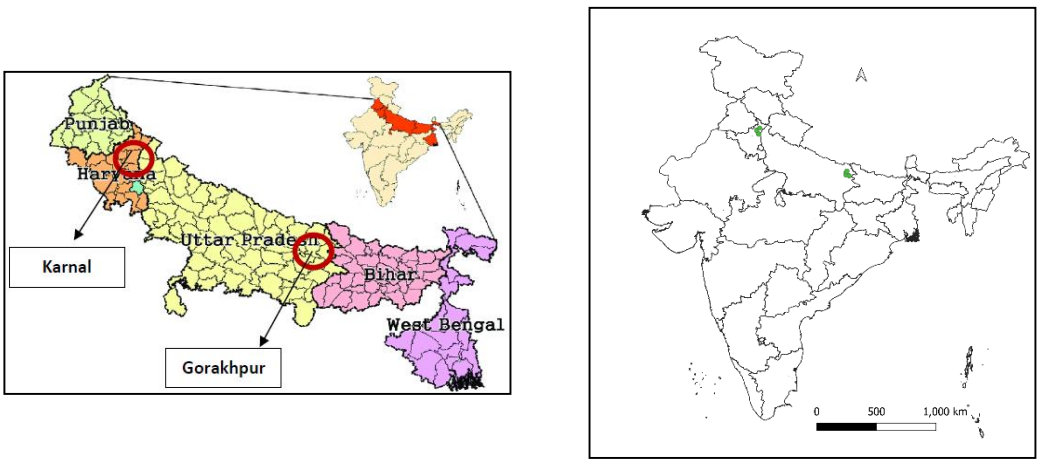
Technological and policy interventions can help address the problem of fertilizer overuse [17]. Amongst the strategies, organic fertilizers can act as a useful measure towards this end [18]. Organic fertilizer application has several potential benefits in the form of improving soil structure [19] and synergistic effect on soil microbial diversity [20] in addition to the production of safer food for the consumers that fetches premium prices in the market [21]. The gradual improvement in the soil properties due to organic fertilizers will result in higher crop yields also [22]. Considering these potential benefits, the use of organic fertilizers (alone or) and the reduced level of chemical fertilizers can contribute towards a sustainable future [23, 24]. The government of India has also emphasized this recently by setting up schemes like Paramparagat Krishi Vikas Yojana, Rashtriya Krishi Vikas Yojana, National Mission for Sustainable Agriculture, National Program for Organic Production, and National Project on Organic Farming that promotes organic fertilizer use in farming [25, 26]. Though the benefits of using organic fertilizers are widely recognized, its adoption at the farm level is still low in India, owing to several constraints [27]. The risk associated with using organic fertilizers in reduced yields, increased pest attack, disease incidence, and higher production cost could discourage the farmers from its use [28]. The fertilizer selection (chemical or organic) and application (rate of application) by the farmers may depend on several factors [1]. The farmer and farm-specific characteristics, Farmers' expectation of profits, the prevailing policy

regime, and sales/marketing channels or arrangements can all affect the organic fertilizer adoption and level of use [7]. Farmers' perception of organic fertilizers and their risk attitude is another vital factor determining this technology's adoption [29, 30]. The perception of the farmer that the use of organic fertilizers may affect his crop revenue negatively is the biggest hurdle in the adoption of this technology. To test this empirically, we use data from a comprehensive rural household survey in the Indo-Gangetic plains. Farmers cultivating rice are included in this study, as the rice-wheat farming system is most common in the region [31]. Farmers in the region follow input-intensive farming practices since the green revolution, and hence it is an excellent case to study their perception and preferences towards organic fertilizers. The study explores the adoption of organic fertilizers by the farmers and identifies the driving factors. We also test whether the adoption of organic fertilizers reduce the crop revenue.

Data and methodology

The study utilizes the data collected from 400 rice farmers of the IGP, India, from March to June 2020. IGP region of India is vast, spanning from Punjab in the North-west to West Bengal in the East [32]. Farmers there follow an input-intensive rice-wheat cropping system, and a large number of them grow Basmati rice that fetches premium prices in the international market [33]. Yield stagnation, the decline in the groundwater table, soil degradation, and atmospheric pollution question cropping sustainability [34]. Nevertheless, excessive fertilizers, especially N, continue in the region, leading to nitrate leaching and further groundwater pollution [35]. Along with this, the inadequate use of organic manures increases the risk of the crop's low yield response [36]. Judicious use of chemical fertilizers, along with organic fertilizers, as per the results of a soil test, is the key to sustain the cropping system [37]. These prevailing cropping practices and resulting sustainability and environmental concerns encouraged us to select IGP to study organic fertilizer usage. We

used a multi-stage sampling technique was used to collect the primary data from the IGP. In the first stage, we randomly selected Karnal from Upper Gangetic Plains and Gorakhpur from Middle Gangetic plains, from 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 both the districts (Karnal block from Karnal district and Bansgaon block from Gorakhpur district) based on the maximum area under rice cultivation. We randomly selected four villages (Kalampura, Kachhwa, Sangohi, and Landhora from the Karnal block; Basauli, Dhobauli, Siswan, and Bharohia from Bansgaon block) and surveyed the farmers. In the final stage, 50 farmers were selected randomly from each of the eight selected villages that enabled us to collect data from a total of 400 rice farmers, of which only 32 percent of farmers adopted organic fertilizers. The data required for the study was collected using a structured schedule that consisted of questions on the demographic characteristics, household characteristics, farm characteristics of individual farmers, and farming practices followed by them. We also included questions on farmers' perception of organic fertilizers and their risk preferences.



(**a**) (**b**)

Figure 1. Map of the study area (Indo-Gangetic Plains region of India): (a) Study districts from the IGP selected for the primary survey; (b) Location of the sample villages

The adoption of organic fertilizers is a dichotomous variable that takes value of '1' if the farmer used organic fertilizers in cultivation and '0' otherwise. We employ a probit regression model to identify the correlates of organic fertilizer adoption. The socio-economic characteristics, farm specific characteristics as well as the farmers' perception on organic fertilizers are tested for covariates in the probit model. To test the effect of organic fertilizer use on crop revenue, we use the Regression adjustment (RA) model. RA estimators use the contrasts of the averages of treatment-specific predicted outcomes to estimate treatment effects. RA fit separate regression models of the outcome on a set of covariates for each treatment level, and compute the averages of the predicted outcomes for each subject and treatment level.

Results and Discussion

Descriptive statistics of the variables used

Among the 400 farmers surveyed, while all the farmers used chemical fertilizers, only 32 percent used organic fertilizers in their rice fields. Farmers, on average, spent five times more on chemical fertilizer in comparison to organic. The farmers' average risk score was 3.38, indicating a relative risk preferring group (1=most risk-averse, 5=most risk preferers) who are ready to invest in newer technologies. While 17 percent of the farmers have attended at least one training on organic fertilizers, 26 percent happened to be members of any farmer organization or cooperative. Table 1 presents the descriptive statistics of the variables used in the study along with the equality of means for organic fertilizer adopters and non-adopters. Adopters are significantly different from non-adopters in terms of age, education, farming experience, tenancy status, membership status in farming organizations, as well as on their perception towards organic fertilizers. Interestingly there was not significant difference among the adopters and non-adopters in the use of chemical fertilizers, suggesting that even

the organic fertilizer adopters use almost the same amount of chemical fertilizers as the non-adopters.

Table 1. Socioeconomic characteristics of the sample households by adoption status.

Variables	Mean	Non-adopters (mean	Adopters (mean)	Mean Difference
Gender (male=1, female=0)	0.96	0.963	0.945	0.018
Age (years)	48.01	50.346	43.031	7.314***
Disadvantaged section (yes=1, no=0)	0.10	0.114	0.055	0.059*
Education (years)	7.84	6.842	9.969	-3.127***
Farming experience (years)	29.57	31.879	24.664	7.215***
Tenant (yes=1, no=0)	0.23	0.272	0.148	0.124***
Hold soil health card (yes=1, no=0)	0.51	0.426	0.695	-0.269***
Member in farm organization (yes=1, no=0)	0.27	0.114	0.586	-0.472***
Training in organic fertilizer (yes=1, no=0)	0.17	0.007	0.523	-0.516***
Distance between farm to home (near=1, far=0)	0.79	0.772	0.813	-0.04
Area under crop (hectares)	1.64	1.256	2.457	-1.201***
Chemical fertilizer use (kg)	190.21	186.973	197.078	-10.105
Farmers' perception on organic fertilizers				
Organic fertilizer use will reduce crop yield (5-point scale: 1=strongly agree; 5=strongly disagree)	3.08	2.71	3.867	-1.158***
Organic fertilizer use will increase the output price (5-point scale: 1=strongly agree; 5=strongly disagree)	2.53	2.632	2.305	0.328***
Organic fertilizer use will increase pest and disease incidence (5-point scale: 1=strongly agree; 5=strongly disagree)	3.08	2.801	3.656	-0.855***
Organic fertilizer use will improve market acceptance of the produce (5-point scale: 1=strongly agree; 5=strongly disagree)	2.64	2.801	2.289	0.512***
I need sale contracts for using organic fertilizer (5-point scale: 1=strongly agree; 5=strongly disagree)	2.63	2.441	3.023	-0.582***
My produce should be certified if I use organic fertilizer (5-point scale: 1=strongly agree; 5=strongly disagree)	2.40	2.037	3.172	-1.135***
I need subsidies for using organic fertilizers (5-point scale: 1=strongly agree; 5=strongly disagree)	2.18	1.261	4.141	-2.880***
I require better extension services for using organic fertilizer (5-point scale: 1=strongly agree; 5=strongly disagree)	2.04	1.46	3.281	-1.822***

Covariates of organic fertilizer adoption- Probit model

The estimates of the probit model for organic fertilizer adoption is presented in the Table 2. Age, education, tenancy status, membership in farm organizations, distance between farm to home, soil fertility, and chemical fertilizer use determine the adoption of organic fertilizers. Besides this, among the variables that capture the farmers' perception, their perception on the effect of organic fertilizers on yield and market acceptance, and their requirement of certification of products and better extension service also determine its adoption. The farmers who perceived that the yield would not reduce and pests and disease attacks will not be higher due to organic fertilizer use were found to have a higher chance of adoption. Membership in farmer organizations and participation in organic fertilizer training also determined the adoption positively and significantly. Farmers who are young, educated, having membership in farmer organizations, participating in organic fertilizer training, and having a positive perception of organic fertilizers adopt organic fertilizers have higher chance of adoption. However, the farmers using higher level of chemical fertilizers have lesser probability of organic fertilizer adoption.

Table 2. Probit estimates of organic fertilizer adoption

Variables	Coefficient	Marginal effect
Gender	-1.591 (2.382)	-0.029
Age	-0.405* (0.218)	-0.007
Disadvantaged section	5.335 (3.483)	0.077
Education	0.842* (0.452)	0.015
Farming experience	0.093 (0.108)	0.002
Tenant	-5.144* (2.945)	-0.041
Hold soil health card	-0.961 (1.347)	-0.016
Member in farm organization	8.086** (3.873)	0.120
Training in organic fertilizer	7.354 (7.595)	0.127
Distance between farm to home	3.620* (2.110)	0.033
Soil fertility	-1.224* (0.730)	-0.022
Chemical fertilizer use	-0.036* (0.020)	-0.001
Organic fertilizer use will reduce crop yield	2.859** (1.370)	0.051

Organic fertilizer use will increase the output price	-1.164 (0.810)	-0.021
Organic fertilizer use will increase pest and disease incidence	2.539 (2.404)	0.045
Organic fertilizer use will improve market acceptance of the produce	-6.123** (3.048)	-0.109
I need sale contracts for using organic fertilizer	-0.533 (0.587)	-0.009
My produce should be certified if I use organic fertilizer	3.023** (1.450)	0.054
I need subsidies for using organic fertilizers	6.448**(3.063)	0.115
Constant	-1.208 (4.793)	
Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1		

Impact of the organic fertilizer adoption on crop revenue- Regression Adjustment

The impact of organic fertilizer adoption on crop revenue was assessed using RA and the result is presented in the Table 3. Our analysis could not find any significant effect of the organic fertilizer adoption on crop revenue. This may be due to the fact that the crop produces from all the farmers receive similar prices in the market at present. Though outputs produced exclusively using organic inputs receive premium prices in the market, use of organic fertilizers to complement the chemical fertilizers doesn't ensure better market prices. This finding is important since, farmers in general perceived that they will have to compromise with crop yields if they adopt organic fertilizers. The revenue that they may have to forego is the major hurdle in its adoption. Thus the finding that organic fertilizer adoption will not alter the crop revenue received by the farmers is in fact encouraging news for the farmers who remain in non-adopters only for the revenue concerns.

Table 3. Impact of organic fertilizer adoption on the crop revenue

ATET	Coefficient	Robust Std. Err.	z	P>|z|
Organic farming adoption	-31944.8	21329.85	-1.5	0.134

Conclusion

Using data from a comprehensive survey of rice farmers in IGP, India, we studied the adoption of organic fertilizers. We used the probit model to study factors determining the adoption. We add valuable information to the literature by linking farmers' future revenue expectations, the prevailing marketing arrangements, socioeconomic factors, policy environment, and perception towards technology adoption. The findings are relevant since the adoption of organic fertilizers in the region was found to be lower, hence can contribute to suggesting the policy options to increase its usage. We couldn’t identify any significant reduction in the crop revenue due to the adoption of organic fertilizers. We found that, in general young, educated farmers having membership in farmer organizations, and perceived positively the effect of using organic fertilizers were the adopters. Our findings have some policy implications as well, especially concerning the future strategies of soil fertilization in the region. First, the government should encourage the farmers to join together, form groups, and take collective farming decisions suitable to the local soil properties. The uneducated, older, and untrained farmers could also get the benefits of organic fertilizers. Second, since the positive perception towards organic fertilizers plays a crucial role in its adoption and level of usage, more efforts on popularizing the benefits of the technology should be undertaken by the government since it takes time before the technology reaches the majority. The problem with organic fertilizers is that their benefit may not have immediate visibility. The extension system has a huge role to play here to assure the farmers of the benefits of continuing with its usage. Finally, if generated from different locations and conditions, more research evidence can help validate the findings that can guide policymaking to benefit a broader set of farmers, nationally and internationally.

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