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Effectiveness of neem coated urea on the productivity of rice in India: A field-based study

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Abstract
This article explores the effectiveness of Neem Coated Urea (NCU) on productivity, income, and adoption behaviour toward NCU among rice farmers across the selected states of India. A total of 1,000 respondents from five states were interviewed for the study. The study has uncovered that, in aggregate, about 90% of the farmers were aware of NCU. The average main product yield of rice is found to be highest in the case of NCU users (22.52 qtls/acre) as compared to NU users (20.90 qtls/acre). In total, the added returns due to the NCU application work out to Rs 2,942/acre with a BCR of Rs 4.28.

Keywords: Slow-release of nitrogen, improving the nitrogen absorption, increasing P and K efficiency to a significant extent, cut down the environmental hazards, partial budgeting technique, Benefit-cost ratio

Introduction

Global fertilizer consumption is expected to exceed 200.5 million tons by 2019-20, a 25% increase over 2008 (FAO, 2015). Asia is the largest consumer of fertilizer in the world and relies on the import of all three major nutrients. With the highest proportion of irrigated land (36.8%), India ranked 57th in terms of fertilizer consumption, consuming 165.1 kg per ha of arable land (World Bank, 2017). Among crops, maize, wheat, and rice (cereals) are the three main fertilizer-consuming crops, with their consumption shares being relatively the same, i.e., 14–16 percent each (Patrick Heffer, 2010) [10]. The increasing production trend over the years in terms of agricultural crops, especially food grains, has been the result of an increased consumption of chemical fertilizers and the adoption of high-yielding varieties (HYVs) across the country, along with an expansion in groundwater irrigation. However, it is pertinent to note that this in turn has resulted in nutrient deficiencies in soils and thereby deficiency symptoms in plants. Therefore, to increase the yield levels, the demand for fertilizers has been growing across India as part of meeting the food security needs of the growing population.

Out of 17 nutrients, which are essentially required by the plants for their normal growth and reproduction, nitrogen is usually required in a much larger quantity than the other fertilizers. Nitrogen is one of the most widely used sources of N fertilizer in the world. The wide acceptance of urea is due to its agronomic acceptability and relatively lower cost as compared to other chemical fertilizers. The main reasons behind "N" deficiency in crops are losses of "N" through leaching, volatilization, surface run-off, DE nitrification, and plant canopy. Further, intensive agricultural production systems and the low rates of N fertilizers are the other reasons for "N" deficiency in crops in the context of developing countries (Fageria *et al*., 2003a) [17]. There has been a great interest in improving nitrogen use efficiency (NUE) through optimization of nitrogen use. In this respect, there exists a substantial empirical literature dealing with the demerits of urea, its adverse environmental benefits through excessive nitrogen losses, and the need for the development of new methods for improving the NUE in crops. In this regard, neem-based pesticides or chemicals are found to be much safer as they have no ill effects on humans or animals or residual effects on agricultural produce (Bains *et al*., 1971) [8]. They were the first to have reported an increased NUE after treating urea with an ethanol extract of neem seed. The application of NCU has helped to reduce environmental hazards and the use of NCU is found to be effective in improving the uptake of N, P, and K to a considerable extent. Based upon the results of extensive field trials, NCU has come to be considered agronomic ally superior to normal urea.

Realizing the various benefits associated with neem coating and its positive effects on the environment, National Fertilizer Limited (NFL) developed a process for the production of Neem Coated Urea (NCU) on a commercial scale in 2002. Later, realizing NCU's potential and farmer acceptance, the Ministry of Agriculture, Government of India, included NCU in the Fertilizer Control Order (FCO) in July 2004. Thus, NFL became the first company in India to have been permitted to produce and market NCU. This was mentioned in Government of India Notification No. SO.807 (E) dated July 9, 2004. In the initial years, the total production of NCU was limited to 35 percent. Later, from March 2015, the Department of Fertilizer (DOF) made it mandatory for all indigenous producers of urea to produce 75 percent of their production as NCU, and from May 25, 2015, the cap was increased to 100 percent.

NCU is superior to normal urea (NU), as indicated by extensive laboratory and field experiments conducted by various scientists in the worldwide. The application of NCU minimizes loss due to leaching; prevents its misuse; places the fertilizer in a slow release mode, thereby nourishing the saplings for a longer period; avoids repeated use of fertilizers and reduces the amount of urea required by crops (enhancing nitrogen-use efficiency); increases the shelf-life of the product; reduces caking during storage and improves the availability of nitrogen to crops; results in a better crop yield and efficient pest control; Further, there was a notion that NCU had stopped the diversion of urea for non-agricultural or industrial purposes. Keeping this in view, the Government of India included neem-coated urea, a slow-release fertilizer, in the Fertilizer (Control) Order, 1985, besides making it mandatory for all the indigenous producers to produce 100% of their total subsidised urea in the form of NCU from 2015. Further, it has since taken various steps to promote NCU use with a view to improve the soil health status and also realising a higher yield per hectare of major crops. Rice (*Oryza sativa* L.), an important crop, forms the staple food for about 65% of the population in India. It plays a vital role in strengthening food and livelihood security. Despite stagnant areas during the last decade, rice production has registered an increase of 18%. Further, India is one of the world's largest producers of rice (white rice and brown rice), with a 20 percent share in the World's rice production. But there is a common concern about declining profitability and increasing production costs in rice cultivation. This article explores the adoption behavior of NUC farmers and the benefits of NUC use on rice yield and income in major rice-growing states.

Data and methodology

The present study relied on primary and secondary data collected from selected states in India, with the reference period being Kharif 2015. Rice crops accounting for the highest urea consumption in each of the selected states were considered for the study. Two districts were selected from five major states, namely, Punjab, Karnataka, Madhya Pradesh, Assam, and Bihar, based on the highest area under rice and their urea usage within the state. From each district, two taluks or tehsils were selected based on the same criteria. Within the selected taluks, two clusters of villages, comprising 3–4 villages per cluster, were selected for conducting the survey. A total of 50 farmers were chosen from each taluk, bringing the total number of farmers in each district to 100. Thus, the total sample size comprises about 1000 respondents from five states. Households were chosen at random to evaluate NCU fertilizer use and its effects on rice yield. The households were classified into two categories, such as NCU users and non-NCU users (normal urea users), mainly to examine the benefits of NCU as compared to NU. Thus, a total of 200 (NU/normal urea) rice farmers were interviewed using a pretested structured questionnaire. Ample care was taken in the selection of a representative sample based on the size of the operational land holdings.

Results and Discussion

Rice cultivation dates to antiquity and was most likely a staple food and the first crop cultivated in Asia. In India, rice has been cultivated since ancient times. This is supported by archaeological evidence and by the numerous references made to rice in ancient Hindu scriptures and literature. Carbonized rice grains were found in the excavation at Hasthinapur (Uttar Pradesh), at a site dated between 1000 and 750 B.C. This is the oldest rice specimen yet known in the world. From the study of Sanskrit and of other different languages in Southeast Asia, many investigators have come to the conclusion that rice was known in India before the present era. Decandolle (1886) and Watt (1892) thought that South India was the place where cultivated rice originated. Vavilov (1926) suggested that India and Burma should be regarded as the centres of origin for cultivated rice. The leading countries producing rice are Japan, Brazil, China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, and the Philippines. In India, rice is grown in almost all the states. Andhra Pradesh, Bihar, Uttar Pradesh, Madhya Pradesh, and West Bengal lead in the area. West Bengal and Uttar Pradesh have the highest rice production. The average yield per hectare is highest in Punjab (3346 kg/ha). However, rice is considered a ‘water guzzler," and the unfavorable monsoon adversely affects its area, production, and productivity in the country (Bouman 2009). Despite a lower growth in the area under rice during the post-green revolution period (1971–90) as compared to the pre-green revolution era (1950–70), rice production registered almost identical growth during both periods. Rice production increased by twofold from 20.58 million metric tonnes to 42.22 million metric tonnes during the pre-green revolution period, mainly due to an increase in area, whereas production doubled during the 23 years of the post-green revolution period (1971–1994), which was attributed to an increase in productivity.

General characteristics of the sample households

The general characteristics of rice farmers are shown in Table 1. The table reveals that the average age of rice farmers was 46 years, with most of them being male respondents. On average, the family consists of seven members, of which three are engaged in farming with an experience of 23 years. With regard to the literacy level, a majority (44%) of them have studied pre-university and above, followed by matriculation (20%), higher primary (19%), and primary schooling (8%); however, about 9 percent of them are also found to be illiterate. Majority of the sample farmers belong to the general category (52%), followed by Other Backward Classes (OBCs) (38%), Scheduled Castes (6%), and Scheduled Tribes (5%).

Table 1: General characteristics of the sample households (n= 1000)

Sl. No.	Particulars	Rice
1.	Average age of respondents (Years)	46
2.	Male respondents (%)	99.30
3.	Average family members engaged fully in farming (No.)	3
4.	Average years of farming experience	23
5.	Average family size (No.)	7
6.	Literacy level (% farmers)	
i	Illiterates	9.40
ii	Primary (1 to 4)	8.20
iii	Higher primary (5 to 9)	19.10
iv	Matriculation (10)	19.70
v	Pre-University (10+2) & above	43.60
7.	Caste (% farmers)	
i	General	51.90
ii	OBC	37.70
iii	SC	5.80
iv	ST	4.60
v	Others	-

Awareness status of NCU Farmers

The awareness and sources of information about NCU among rice farmers in the study area are presented in Table 2 and Figure 1. It is revealed from the table that, overall, about 90 percent of the farmers are aware of NCU. However, across states, the awareness level is much higher in Bihar (99.50%), followed by Punjab (98.50%), and Madhya Pradesh (94.50%) as compared to the aggregate level. The level of awareness is much lower in Karnataka (67%) as compared to Assam (89%).

With regard to sources of awareness (Figure 1), overall, input suppliers and cooperatives (43%) are a major source of information for farmers, followed by agricultural officers (19%). About 17 percent of the farmers were found to have gotten the information from their fellow farmers. Similarly, across states, a major source of information appears to be input suppliers or cooperatives. In the case of Punjab, as many as 90% of farmers reported learning about NCU from input suppliers or cooperatives, followed by farmers in Bihar (60%) and Assam (45%). Input suppliers are the major source of information on NCU for about 22 percent of the farmers in Karnataka. As usual, agricultural officers from the respective state departments of agriculture are the second most important source of information for farmers in Madhya Pradesh (65%) and Karnataka (20%). While about 24–26 percent of the farmers from Assam and Madhya Pradesh are their fellow farmers, they are the major source. Interestingly, about 29 percent of the farmers in Karnataka have reported other sources, such as friends and relatives, companies, and KVKs, with regard to the creation of awareness regarding the utility of NCU. Other than these sources, print and visual media, agricultural universities, and farmer facilitators have also contributed to some extent.

The results indicate that a large proportion of the farming community continues to be unaware of NCU use in the study area, despite the presence of varied sources. Nevertheless, whether farmers are aware or not of NCU use, special efforts are needed to create awareness regarding the potential benefits of NCU usage vis-à-vis NU among the farming community, considering that the government has made 100% production of NCU mandatory) since, May 2015.

Table 2: Awareness status and sources of information on NCU

Sl. No.	Sources of Information	Punjab	Karnataka	Madhya Pradesh	Assam	Bihar	Overall
1	% of farmers being aware of NCU use	98.50	67.00	94.50	89.00	99.50	90.10

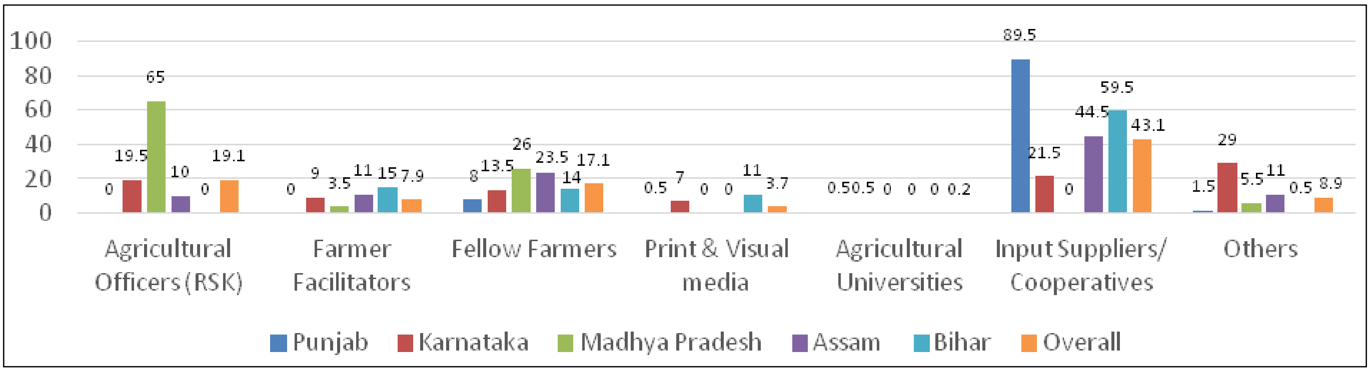

Fig 1: Sources of information on NCU (% of Farmers)

Perceptions of NCU in relation to NU

Table 3 depicts the perceptions of farmers regarding NCU use in relation to NU. About NCU quality, a majority of the farmers have opined that the quality of NCU is good (56%). Regarding NCU availability, a majority of the farmers have opined that the availability is adequate (51%), compared to NU. Undoubtedly, about 72 percent of farmers have reported the timely availability of NCU for Kharif 2015. According to more than half of the sample farmers, the price of NCU is reasonable, not very high, while approximately 30% of the farmers stated that the price of NCU has not changed and remains the same as the price of urea. This is mainly because sellers and input dealers sell both NCU and NU at the same price in order to make some profit, even though there is a slight increase in NCU prices due to the additional cost of neem coating. Benefits of NCU In terms of the total fertilizer usage and urea usage, the majority of the farmers (65 and 68 percent) have experienced no change in the total fertilizer usage and urea usage, respectively. Interestingly, more than 50 percent of farmers have noticed there is no change in pest and disease attacks. On the contrary, according to 46% of farmers, there has been a decline in pest and disease attacks post-NCU usage. Similarly, about 54 percent of farmers have expressed that NCU is more easily accessible in the market as compared to NU. Overall, we can conclude that for a majority of the farmers, the quality, adequacy, and timely availability of NCU are good and have improved further post-mandatory production and distribution of NCU as compared to NU, while the prices have increased slightly. Further, the usage of total fertilizers and urea fertilisers is more or less the same. The incidence of pest and disease attacks has also decreased. The accessibility of NCU has improved post-mandatory production as compared to NU in the selected states. However, a few farmers have reported a reduction in the cost of pest and disease control, as well as a reduction in the application of total fertiliser and urea following the market introduction of NCU.

Table 3: Perceptions of NCU in relation to NU

Sl.	Particulars	Percent
1	**Neem Coated Urea quality**	
	Very good	17.30
	Good	56.00
	Bad	8.50
	No change	18.20
2	**Neem Coated Urea availability**	
	Adequate	51.30
	Inadequate	8.50
	No change	40.20
3	**Timely availability of Neem Coated Urea**	
	Yes	71.50
	No	28.50
4	**Neem Coated Urea Price**	
	Very high	0.20
	High	38.80
	Not very high	29.40
	Same as urea	31.60
5	**Benefits of NCU in terms of total fertilizer usage**	
	Increased	13.40
	Decreased	21.80
	No Change	64.80
6	**Benefits of NCU in terms of Urea usage**	
	Increased	16.30
	Decreased	15.90
	No Change	67.80
7	**Pest and disease attack**	
	Increased	0.80
	Decreased	46.10
	No Change	53.37
8	**NCU is more easily accessible in the market as compared to normal Urea**	
	Yes	53.70
	No	46.30

Benefits of NCU on production and marketing

During the reference period (Kharif 2015), both NU and NCU were available in the market across the study area before the government made the production and distribution of NCU throughout the country mandatory. Therefore, an effort was made by the study to compare the benefits of NU and NCU on the production and productivity of the rice crop across states in India. The details of the benefits of NCU on rice production and marketing are presented in Table 4. At the aggregate level, the average main product yield of rice is found to be highest in the case of NCU users (22.52 quintals per acre) as compared to NU users (20.90 quintals per acre), which accounts for a statistically significant increase in yield of 7.75 percent. This is due to the presence of neem content in urea, which slows down the release of nitrogen. As a result, "N" is available to plants for a longer period as compared to "NU" and concomitantly reduces the frequency of application and quantity of urea consumption. These findings are consistent with those of John *et al*. 1989 [19]; Agostini *et al*. (2010) [1]; Akiyama *et al*. (2010) [6]; Aziz *et al*. (2009) [7]; Bains *et al*. (1971) [8]; and Biswas *et al*. (2010) [9], who discovered a significant increase in rice grain yield in subsequent field experiments. However, across states, the scenario seems to be different, with the increase in yield levels of rice being much more than the aggregate figures in the case of Madhya Pradesh (16.58%), followed by Karnataka (10.83%) and Bihar (9.42%) in the order of importance, while the increase is less observed in respect of Assam (5.34%) and Punjab (0.97%). All these results are found to be statistically significant at about a five percent level.

Similarly, in terms of by-product yield, the aggregate yield shows an increase from 31.59 quintals/acre to 32.41 quintals per acre after the application of NCU in place of NU. This increase in the by-product yield amounts to 2.59 percent as compared to the yield levels in the context of the NU application. Across different states, the highest percent change in by-product yield is noticed in the state of Bihar (7.60%), followed by Madhya Pradesh (5.28%), Assam (5.41%), Punjab (3.45%), and Karnataka (3.45%). This increase in yield is found to be statistically significant. Excepting Karnataka, the prices of the main product appear to be relatively the same across states and all of India. The percent change post-NCU application in the place of NU varies within two percent, whereas, only in the case of Karnataka, the prices seem to have decreased to the tune of 0.33 percent, which may be due to market imperfections. Overall, there is an increase in the main product price to the extent of Rs. 8 per quintal with respect to NCU, indicating a percentage change of 0.58 percent. Similarly, in the case of the by-product price, the percent change in respect of NCU as compared to NU amounts to 8.98 percent. The increase in the price of the by-product from Rs. 167/bundle (without NCU) to Rs. 182/bundle (with NCU) might be attributed to the application of NCU in addition to many other factors. Further, a majority of the farmers have also reported an increase in the quality of both the main product and by-product yields post-NCU application. With respect to statistical significance, most of the prices across states appear to be non-significant. Depending upon the prices of both the main product and by-product, the value of the main product and by-product showed an increase of 8.23 percent and 23.87 percent, respectively, after the adoption of NCU in place of NU at the aggregate level. Like the prices of the main product and by-product, a majority of the prices across states and all of India are found to be statistically non-significant in the case of rice, except for Assam and Madhya Pradesh, in respect of which the prices are found to be statistically significant at the one percent level for both the values of the main product and by-product

Table 4: Benefits of NCU on production and marketing (Quintals/Acre)

Particulars	Karnataka		Assam		Bihar		Madhya Pradesh		Punjab		All India	
	NCU	NU	NCU	NU	NCU	NU	NCU	NU	NCU	NU	NCU	NU
Main product yield (quintal)	28.94	26.11** (10.83)	13.80	13.10*** (5.34)	26.82	24.51** (9.42)	14.06	12.06*** (16.58)	29.00	28.72*** (0.97)	22.52	20.90*** (7.75)
By-product Yield (quintal)	62.37	60.29* (3.45)	8.97	8.51*** (5.41)	4.67	4.34** (7.60)	23.69	22.50* (5.28)	62.35	58.14* (7.24)	32.41	31.59Ns (2.59)
Price of main product (Rs/ quintal)	1804	1810 NS (-0.33)	1137	1122** (1.33)	1093	1089Ns (0.36)	1382	1354Ns (2.06)	1450	1450NS (0.00)	1373	1365*** (0.58)
Price of by-product (Rs/ quintal)	84	71NS (18.30)	350	350NS (0.00)	199	198Ns (0.50)	155	120Ns (29.16)	120	98** (22.44)	182	167** (8.98)
Value of main product (Rs)	52,208	47268NS (10.47)	15691	14698*** (6.75)	29314	26691** (9.82)	19431	16329*** (18.99)	42050	41644** (0.97)	31740	29326Ns (8.23)
Value of by-product (Rs)	5,248	4,289*** (22.36)	3139	2979*** (5.37)	929	859Ns (8.15)	3672	2700*** (36.00)	7482	5697.72* (31.31)	4094	3305Ns (23.87)

Note: ***, ** & * indicate 1, 5 and 10 percent level of Significance, respectively; Figures in parentheses indicate percentage change

Benefits of NCU use on the cost component

Table 5 compares the input costs of rice farmers employed by NCU and NU. A perusal of the table reveals that, at the aggregate level, the total cost of the selected inputs shows an increase for the users of NCU (Rs. 8107 per acre) as compared to NU users (Rs. 7759 per acre) to the extent of 4.48 percent, while the cost shows a decreasing trend in respect of all the parameters, except for the cost of other fertilizers. The decrease in cost of pest and disease control, weed management, and NCU/NU works out to 6.26, 5.32, and 0.19 percent, respectively, and is mainly due to the adoption of NCU in place of NU. Interestingly, all these figures are found to be statistically significant at about a 10 percent level. Further, these results are in conformity with the secondary data published by the DES in 2014–15. Across states, the results are comparatively the same for the cost of pest and disease control and the cost of weed management. with the proportion of decrease ranging from nearly 3% to 13.50% in the case of pest and disease control and from 0% to 20.19% in the case of weed management costs. However, with regard to the cost of NCU and NU and of other fertilizers, the results show a different picture across states in that the cost of NCU and NU has decreased in the case of Assam (17.59%), followed by Karnataka (3.53%), and Bihar (2.04%), whereas the cost seems to have increased in Punjab (13.8%), followed by Madhya Pradesh (6.32%), post the application of NCU in place of NU. These results are consistent with the findings of Ramappa, KB, *et al*. (2022) [20], Prasertsak P, *et al*. (2002) [3], Probert ME, *et al*. (1998) [4], and Pasley H, *et al*. (2021) [2], who discovered a significant increase in the main product and by-product of rice yield by applying neem-coated urea in successive field surveys, slow-release fertilizer, and nitrate leaching. Similarly, the cost of other fertilizers has decreased with reference to Assam (15.66%), followed by Madhya Pradesh (11.37%), while on the other side, the cost of other fertilizers has increased in respect of Bihar (19.96%), followed by Karnataka (17.45%), and Punjab (3.82%) because of the usage of NCU instead of NU. Overall, the total cost shows an increase to the extent of 16.59 percent in the case of Bihar, followed by Karnataka (7.92%), while decreasing in respect of Assam (10.36%), Madhya Pradesh (9.97%), and Punjab (4.17%) in the order of magnitude.

Table 5: Benefits of NCU use on the cost component (Values in Rs/Acre)

Particulars	Karnataka		Assam		Bihar		Madhya Pradesh		Punjab		All India	
	NCU	NU	NCU	NU	NCU	NU	NCU	NU	NCU	NU	NCU	NU
Cost of pest and disease control	4346	4512* (-3.68)	222	244*** (-9.01)	398	421Ns (-5.46)	324	334** (-2.99)	1518	1755* (-13.50)	1362	1453** (-6.26)
Cost of weed management	491	509** (-3.53)	1312	1350Ns (-2.81)	328	411* (-20.19)	301	301NS (0.00)	411	435Ns (-5.51)	569	601*** (-5.32)
Cost of NCU / Normal Urea	627	650NS (-3.53)	356	432*** (-17.59)	574	586** (-2.04)	252	237* (6.32)	742	652* (13.80)	510	511*** (-0.19)
Cost of other fertilizers	8080	6879*** (17.45)	1179	1398** (-15.66)	12608	10510* (19.96)	5786	6529*** (-11.37)	678	653Ns (3.82)	5666	5194* (9.08)
Total Cost	13544	12550** (7.92)	3069	3424*** (-10.36)	13908	11928** (16.59)	6663	7401** (-9.97)	3349	3495Ns (-4.17)	8107	7759*** (4.48)

Note: ***, ** & * indicate 1, 5, and 10 percent level of Significance, respectively**;** Figures in parentheses indicate the percentage change

Economic feasibility of NCU using a partial budgeting framework

An economic feasibility analysis of NCU use, frequently with and without an NCU approach, has been used to identify and assess the costs and benefits as part of a more meaningful assessment of the current situation. The difference between the costs and benefits is the net incremental benefit arising from the NCU application. However, a before-and-after approach is not used in this framework on account of changes in production that would have occurred due to regular developments along with the NCU application. While assessing the benefits and costs of NCU usage, only incremental net benefits need to be considered, with the reduced benefits treated as costs. The benefits foregone need to be taken into account as a cost component of NCU usage. Thereby, only incremental value could be attributed to NCU. Hence, a partial budget technique is used for assessing the incremental income based on a small change in farm business post-NCU application. In the present study, a partial budgeting technique is used to estimate the variables such as added income, reduced costs, and added costs following a small change in NCU application vis-à-vis NU. The budget indicates whether the change has increased, decreased, or there has been no change in net income due to the adoption of NCU. Also, the partial budget compares both the positive and negative effects of a change due to NCU application in relation to NU or incremental income accruing from reference crops. The benefits of NCU, based on a partial budgeting technique, considering added and reduced costs due to NCU application, are estimated and presented in Table 6. It can be seen from the table that there are positive benefits to the economic feasibility of NCU application on both the main product and by-products of rice. The variables considered for estimating a partial budgeting technique in the study include the cost of pest and disease control, the cost of weed management, the cost of NCU and NU, and the cost of other fertilizers. At the aggregate level, the added costs due to NCU application appear to be as high as Rs. 739 per acre in the case of other fertilizers only and are shown on the left side (A) of the partial budget technique, whereas on the other side (B), a cost reduction due to NCU application is noticed with respect to pest and disease control (Rs. 70 per acre), weed management (Rs. 46 per acre), the cost of NCU (Rs. 37 per acre), and other fertilizers (Rs. 73 per acre), which all together total to Rs. 227 per acre. It is important to note that the cost of other fertilizers is repeated on both sides of the table, in view of its reduction with respect to Madhya Pradesh and Assam states.

It is exceptional to note that, nowhere, reduced returns have been observed; instead, added returns, both in terms of the main product and by-product yields, are being noticed for the users of NCU compared to NU users. In total, the added returns due to NCU application in the case of the main product amount to Rs. 2,809 per acre, and in the case of by-products, they amount to Rs. 134 per acre, which put together works out to Rs. 2,942 per acre. Therefore, the added costs due to NCU application and reduced returns for the same reason work out to Rs. 739/- per acre (Total (A)), while the reduced cost due to NCU and added return due to NCU turn out to Rs. 3170/- per acre (Total (B)). Finally, the net incremental benefit (Total (B) minus Total (A)) amounts to Rs. 2,430 per acre in the aggregate across the study area. This is the positive benefit of NCU adoption in lieu of NU, in addition to other favourable factors. Using the same information, the benefit-cost ratio has arrived at 4.28, meaning that for every rupee of investment in the NCU application, there has been a rise in returns to the extent of Rs. 4.28. Based on these results, it can be concluded that the application of NCU has had positive effects in terms of both increased yield and income due to reduced costs for the rice farmers.

Table 6: Economic feasibility of NCU use for rice (partial budgeting framework)

A			B		
Sl. No.	**Added cost due to NCU**	**Costs (Rs.)**	**Sl. No.**	**Reduced cost due to NCU**	**Returns (Rs.)**
1	Cost of pest and disease control	-	1	Cost of pest and disease control	70.41
2	Cost of weed management	-	2	Cost of weed management	45.98
3	Cost of NCU		3	Cost of NCU	37.22
4	Cost of other fertilizers	739.33	4	Cost of other fertilizers	73.00
	Total added Costs	739.33		Total Reduced cost	226.61
Sl. No.	Reduced return Due to NCU	Costs (Rs.)	Sl. No.	Added returns due to NCU	Returns (Rs.)
1	Main product		1	Main product	2808.81
2	By-product yield		2	By-product yield	133.88
	Total of reduced returns	-		Total of added returns	2942.69
	Total (A)	739.33		Total (B)	3169.64
	B-A	2430.31			

Additional return from NCU Rs. 2430.31

An added return per acre amounts to Rs. 2942.69. B:C Ratio= 4.28

Conclusion

Recognizing the various benefits of NCU and its positive effects on the environment, the Union Government of India has made the production of NCU (100%) mandatory across the country. The aim of the policy is to control an excess use of urea in agriculture while also preventing the diversion of subsidised urea towards industrial purposes. The three farmers' policies appear to have materialized, as diversion has ceased completely since the implementation of NCU. In addition to the increase in yield levels of both the main product and by-products in the rice crop, farmers have reaped the positive externalities of NCU in terms of increased outputs in the rice crop, reduced costs (in terms of pest and disease control), and thereby increased returns. All these benefits might not be related to NCU usage alone, as there might be some other favourable reasons that have contributed to the same as well. However, the usage of NCU relative to NU has not been impressive due to the ignorance of farmers about the potential benefits of NCU over NU and its application. Hence, there is a need for spreading awareness among farmers regarding NCU usage and its benefits through conducting trainings, Organising demonstrations, etc.

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