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# Adoption of Resource Conservation Technologies in Indo-Gangetic Plains of India: Scouting for Profitability and Efficiency

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## Abstract

This study has evaluated the superiority of resource conservation technologies (RCTs) over conventional methods of cultivation and has identified the factors influencing adoption of these technologies. It has provided succinct evidences from four states — Bihar, Haryana, Punjab and Uttar Pradesh — by comparing the adopters and non-adopters of RCTs in the rice-wheat cropping system of the Indo-Gangetic Plains of India. The study has highlighted superiority of RCTs over the conventional practices in terms of cost saving and efficient inputs-use. However, there is a need to internalize the RCTs in their totality by applying plans and strategies based on local dynamics. The study has suggested the need of policy formulations for dissemination and wider adoption of these technologies.

**Key words:** Resource conservation technologies, Economic efficiency, DEA approach, RCTs, Indo-Gangetic Plains, Wheat, Rice

**JEL Classification:** Q30, Q34, Q32

## Introduction

The resource conservation technologies (RCTs) primarily focus on resource savings through minimal tillage, ensuring soil nutrients and moisture conservation through crop residues and growth of cover crops, and adoption of spatial and temporal crop sequencing. These pro-sustainable technologies and the practices therein have long been practised by the farmers in the Indo-Gangetic Plains but got eroded in recent times. With squeezing net returns and increasing threats of sustainability, the viability of rice-wheat farming is looming large. These issues are being discussed and concerns are being raised by the planners and policy makers. Considerable efforts are being made to popularize and increase the adoption of RCTs in the region. In the absence of specific information, however, the policies and efforts are inadequate and ineffective to achieve the desired results in this direction.

The Indo-Gangetic Plain is one of the world's major foodgrain producing regions. The states falling under this region, viz. Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, Bihar and West Bengal, are also the major rice-wheat growing states spread over 10.5 million hectares in the country. During the past 30 years, agricultural production growth in this region has been able to keep pace with population demand for food in the country mainly due to adoption of green revolution technologies inducing yield growth, followed by area expansion. But, this opportunity is ceasing very fast due to limited scope for increasing the availability of arable land and natural resources. The other issue is

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the conservation of the basic resources of land and water for sustainability of agriculture in the Indo-Gangetic Plain. It is generally believed that the rice-wheat system has strained the natural resources in this region and more inputs are required to attain the same yield levels (Swarup and Singh, 1989; Kumar and Yadav, 1993; Lal *et al*., 2004).

It is, therefore, imperative now to promote alternative technologies that would help conserve the much needed but gradually depleting natural resources while boosting productivity growth in the long-run by maintaining soil health and production environment. As a part of this strategy, resource conserving technologies (RCTs) play a major role in sustaining and enhancing the productivity of the rice-wheat system at a lower cost of production. Some of the RCTs that are being promoted in the rice-wheat belt of the Indo-Gangetic Plains are: zero tillage, laser land levelling, bed planting, surface seeding, rotary tillage, use of leaf colour chart, mechanical rice transplanter, etc. The adoption of RCTs is expected to yield benefits to the farmers in terms of reduced losses due to soil erosion, saving of energy and irrigation costs, savings on labour input, increased productivity and water-use efficiency, reduced pumping of groundwater, increased nutrient-use efficiency and adoption of new crop rotations. Although considerable debate is currently going on these issues, in the absence of specific information, the planners and policymakers find it difficult to make suitable policies for popularization/increased adoption of RCTs. Keeping this in view, a study was taken up to:

- Study and evaluate the superiority of resource conservation technologies over conventional methods of cultivation, and
- Identify the factors influencing the adoption of such technologies.

## Data and Methodology

The survey was conducted in four states — Bihar, Haryana, Punjab and Uttar Pradesh — using a well-designed questionnaire and information was collected on various aspects of adoption and impact of RCTs in the Indo-Gangetic Plains in India. The study employed stratified multistage sampling design for selecting the sample units. The above four states were taken as first strata, then within a state, districts, blocks and villages were considered at second, third and fourth levels of study. At the first stage, 2-3 districts were selected on the basis of maximum area under 'Zero Tillage' (ZT) adoption. Thus, Begusarai, Patna and Samastipur districts from Bihar; Karnal and Kaithal districts from Haryana; Ludhiana, Sangrur and Patiala districts from Punjab; and Gorakhpur and Maharajganj districts from Uttar Pradesh were selected. A total of 600 farmers were chosen as sample (100 adopter households and 50 non-adopter households from each state). The primary data pertaining to RCT adoption were collected for the agricultural year 2006-07.

## Analytical Tools

### Economics and Efficiency of Rice and Wheat Cultivation

For analyzing various aspects of the economics of rice and wheat cultivation (adopters vs non-adopters), tabular analysis was carried out. The statistical tools like percentage and average were frequently utilized. To study farm efficiencies of adopters and non-adopters, Data Envelopment Analysis (DEA) was carried out using program version 4.1 & 2.1 developed by Coelli (1994; 1996).

### Factors Influencing RCT Adoption

To identify the factors influencing adoption of RCTs, the logistic model was fitted using the maximum likelihood method, i.e., the coefficient that makes the observed change in log odds associated with one unit change in the independent variable. In the present study, it was hypothesized that the probability of a farmer adopting a resource conserving technology depends upon increase in net income due to adoption of technology, education level of household-head, total irrigated cropped area, source of information, possession of tractor by a farm household and ability of the technology to save resources like labour. The model used in the study can be specified as:

$$Y = g(Z)$$

and

$$Z = F(X_1, X_2, X_3, \ldots\ldots, X_K)$$

where,

Y = Adoption status of a household (Y = 1 for the adopter and Y = 0, for non-adopter households),

Z = Vector of explanatory variable

**Specification of variables used in the logit model**

| Variables | Definition / Codes |
|---|---|
| Dependant variable (Y) | Y = 1, adopter household<br>Y = 0, for non-adopter household |
| Age of the farmer | In years |
| Education | 0= Illiterate, 1= Primary, 2= Matriculation and 3= Graduation and above |
| Farm family workers | In numbers |
| Total irrigated cropped area | In hectares |
| Source of information | 1, if formal and 0, if informal |
| No. of tractors | in numbers |
| Net return = Gross return – cost of cultivation | Income from farming in ₹/ hectare |

$X_1, X_2, X_3, \ldots\ldots, X_k$ = Explanatory variables, and

K = Total number of explanatory variables.

## Results and Discussion

At farmer-field level, out of several RCTs developed and promoted by different institutions, only 'Zero Tillage' and 'Bed Planting' were widely prevalent in the region (Narang and Virmani, 2001). Therefore, a detailed study on adoption and impact of these two technologies was conducted. These two technologies were confined to only rice and/or wheat cultivation in the IGP region, barring few exceptions.

### Economics of Rice and Wheat Cultivation in IGP Region

The cost on cultivation of wheat and rice crops was calculated in each selected state based on the input data gathered from the survey in respect of adopter and non-adopter categories.

### Cost on Cultivation for Rice

Adopters saved in terms of cost on human and mechanical labour (Table 1) in all the four states over the non-adopters. However, they incurred additional cost on FYM in all the four states.

**Table 1. Input cost differential in rice cultivation in IGP region — Adopters vs non-adopters**

(₹/ha)

| Particulars | Bihar | | Haryana | | Punjab | | Uttar Pradesh | |
|---|---|---|---|---|---|---|---|---|
| | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters |
| Cost on human and mechanical labour | 3125 (-19.59) | 3886 | 2859 (-20.77) | 3608 | 2940 (-20.64) | 3705 | 2992 (-22.38) | 3854 |
| Cost on seed | 1409 (-3.45) | 1459 | 1734 (-2.06) | 1771 | 1780 (-2.69) | 1830 | 1594 (-3.42) | 1651 |
| Cost on FYM | 2560 (6.18) | 2411 | 3952 (10.02) | 3592 | 2381 (6.40) | 2238 | 2124 (11.96) | 1897 |
| Cost on plant nutrients | 2688 (-10.36) | 2998 | 3228 (-9.88) | 3582 | 2897 (-7.34) | 3126 | 2699 (-7.17) | 2907 |
| Cost on irrigation | 1399 (-9.60) | 1547 | 2601 (-7.10) | 2799 | 3220 (-9.92) | 3575 | 1167 (-14.75) | 1369 |
| Cost on plant protection | 2188 (-9.02) | 2404 | 1804 (-16.26) | 2154 | 1524 (-14.72) | 1787 | 1594 (-11.45) | 1800 |
| Total input cost | 13367 (-9.10) | 14706 | 16177 (-7.59) | 17506 | 14741 (-9.33) | 16259 | 12169 (-9.71) | 13478 |

*Note:* Figures with negative sign within parentheses indicate the percentage of input cost saving by RCT adopters over non-adopters in respective states, while non-negative figures indicate additional percentage cost

**Table 2. Input saving in rice cultivation by RCT adopters over non-adopters in IGP region**

(Per cent)

| Particulars | Bihar | Haryana | Punjab | Uttar Pradesh |
|---|---|---|---|---|
| Ploughing (No.) | -18.78 | -20.86 | -20.69 | -21.43 |
| Harrowing (No.) | -24.47 | -25.74 | -29.08 | -25.33 |
| Land levelling (No.) | -21.48 | -20.77 | -24.24 | -25.00 |
| Human and mechanical labour (hours) | -21.07 | -22.15 | -26.50 | -20.35 |
| Seed (kg) | -2.42 | -2.22 | -2.91 | -3.65 |
| FYM (Quintals) | 4.25 | 11.36 | 7.28 | 11.11 |
| Urea (kg) | -25.81 | -14.77 | -12.01 | -19.59 |
| DAP (kg) | -14.11 | -16.03 | -19.87 | -10.54 |
| MOP (kg) | -11.92 | 0.00 | 0.00 | -12.09 |
| Other fertilizers (kg) | -19.76 | -17.00 | -18.92 | -19.04 |
| Total plants nutrients (kg) | -19.97 | -15.21 | -14.27 | -15.42 |
| Irrigation (No.) | -8.52 | -9.15 | -9.95 | -8.58 |
| Disease control (kg) | -33.33 | 0.00 | 0.00 | -15.38 |
| Insects control (kg) | -2.08 | -3.89 | -4.14 | -4.94 |
| Total plant protection chemicals (kg) | -6.29 | -3.89 | -4.14 | -6.38 |

*Note:* Negative sign indicates saving of RCT adopters over non-adopters.

The zero tillage provided maximum saving in input cost on human and machine labour in Uttar Pradesh; it was ₹ 862/ha, i.e. around 22 per cent over conventional tillage. In Haryana and Punjab, this saving was around 21 per cent each, followed by Bihar (~20%). Besides labour saving, the adoption of RCTs also helped in saving to the extent of expenditures on seed (2-3%), chemical plant nutrients (7-10%) and irrigation (7-15%), thereby resulting in a total input cost saving of around 8-9 per cent over the non-adopters. The variation in cost of saving across states could be attributed to the methods of their application. These advantages are quite attractive and can serve as incentives to a farmer to switch over to RCTs.

The adoption of RCTs provided a considerable saving in the use of human and mechanical labour, it ranged from 20 per cent to 27 per cent (Table 2). Such saving in labour-use was quite significant under the present scenario of agricultural labour scarcity. Also, there was considerable saving in the use of chemical fertilizers by the adopters. In Punjab, the adopter-farmers saved inputs to the tune of 27 per cent in human and mechanical labour, 14 per cent in plant nutrients, 10 per cent in irrigation, and 4 per cent in plant protection. Thus, with no puddling, RCT emerged as a profitable option for rice farmers in Punjab.

In Uttar Pradesh, the farmers saved maximum on human and mechanical labour (20%), followed by plant nutrients (15%). In Haryana, the adopters saved up to 4 per cent on plant protection chemicals as compared to non-adopters. The adopters of RCTs in Haryana also saved around 22 per cent in input on human and mechanical labour, 15 per cent on plant nutrients and 9 per cent on irrigation. The adopters of RCT in Bihar saved up to 21 per cent on human and mechanical labour, followed by 20 per cent on plant nutrients.

Besides reduction in the input-cost of adopters as compared to non-adopters to the tune of 8-10 per cent (Table 1), there was marginal improvement (3-6%) also in grain yield (Table 3). Moreover, it is noted that the returns over cost were remarkably more of adopters than non-adopters in all the states, with maximum of 32 per cent in UP. The study revealed that the net returns of adopters of RCTs were more than that of non-adopters due to reduced total input-cost. This was also corroborated by Gupta *et al.* (2003).

### Cost on Cultivation of Wheat Crop

Overall, there was a saving in cost of wheat cultivation in all the states; it was maximum in Punjab (16%), followed by Haryana (14%), UP (13%) and Bihar (11%), as depicted in Table 4. The RCT-adopters of Punjab incurred as much as 23 per cent lower costs on human and mechanical labour, besides considerable saving in cost on inputs like seeds, irrigation, weed control, and plant protection chemicals. It is evident

**Table 3. Differential yields and returns from rice cultivation in IGP region — Adopters vs non-adopters**

(per hectare)

| Particulars | Bihar | | Haryana | | Punjab | | Uttar Pradesh | |
|---|---|---|---|---|---|---|---|---|
| | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters |
| Total input cost (₹) | 13367 | 14706 | 16177 | 17506 | 14741 | 16259 | 12169 | 13477 |
| | (-9.10) | | (-7.59) | | (-9.33) | | (-9.71) | |
| Grain yield (tonnes) | 4.0 | 3.9 | 5.0 | 4.8 | 5.4 | 5.0 | 4.3 | 4.1 |
| | (3.25) | | (4.38) | | (5.97) | | (4.85) | |
| Grain price (₹) | 573 | 573 | 607 | 594 | 589 | 590 | 483 | 478 |
| | (0.02) | | (2.19) | | (0.19) | | (1.10) | |
| Grain revenue (₹) | 22946 | 22196 | 30497 | 28522 | 31586 | 29756 | 20928 | 19694 |
| | (3.27) | | (6.48) | | (5.97) | | (5.90) | |
| By product revenue (₹) | 1350 | 1089 | Nil | Nil | Nil | Nil | 2850 | 2584 |
| | (19.33) | | | | | | (9.31) | |
| Total returns (₹) | 24297 | 23285 | 30497 | 28522 | 31586 | 29756 | 23778 | 22278 |
| | (4.16) | | (6.48) | | (4.08) | | (6.31) | |
| Return over cost (₹) | 10929 | 8579 | 14319 | 11016 | 16845 | 13497 | 11609 | 8801 |
| | (27.39) | | (29.99) | | (24.80) | | (31.91) | |
| Return/cost | 1.82 | 1.58 | 1.89 | 1.63 | 2.14 | 1.83 | 1.95 | 1.65 |
| | (14.79) | | (15.71) | | (17.08) | | (18.21) | |

*Note:* Figures within parentheses indicate the percentage change in particulars experienced by the adopters over non-adopters in respective states

from Table 4 that zero tillage in Haryana could reduce input costs to the extent of 21 per cent on human and machine labour, 30 per cent on plant protection chemicals and 7 per cent on seed. In UP, zero tillage had a cost advantage of around 17 per cent in human and mechanical labour, 6 per cent in seed, 10 per cent in irrigation, 21 per cent in weed control, and 19 per cent in plant protection.

Adoption of RCT led to input saving in wheat cultivation of adopters over non-adopters by 100 per cent in ploughing, land levelling and harrowing. Other operations where adopters had advantage included human and mechanical labour, plant protection chemicals, and irrigation (Table 5). In Punjab and Haryana, the adopters saved around 20 per cent on human and machine labour.

The reduction in use of inputs by RCT-adopters did not affect the grain yield of wheat negatively (Table 6), defying the perception of a lower yield on account of RCT adoption as reported by Mehla *et al.* (2000). On the contrary, a higher yield was obtained by adopters as compared to non-adopters; the yield was as high as 8 per cent in Punjab, more than 4 per cent in Haryana, and about 2 per cent each in Bihar and Uttar Pradesh. Consequently, the revenue from grain and by-product as well as net returns and the returns to cost ratio were higher for farmers adopting RCT.

In all the states under study, higher grain yield combined with lower input costs, resulted in higher total returns as well as more returns-over-cost for adopters than non-adopters.

## Economic Efficiency of Farms Adopting RCT

The study revealed a higher percentage of technical efficiency, allocative efficiency and economic efficiency in case of RCT-adopters vis-à-vis non-adopters in all the four states under study, establishing the superiority of RCT over conventional tillage practices in case of wheat cultivation as is evident in Table 7. The maximum difference in efficiencies was found in Bihar while farmers of Punjab showed highest efficiencies with the technical, allocative and economic efficiencies of the adopters being 89, 94 and 83 percent which were respectively higher than 87, 93 and 81 for non-adopters. This is mainly because farmers of Punjab are generally progressive farmers and have better resource-use efficiency than the farmers of other states.

**Table 4. Input cost differential in wheat cultivation in IGP Region — Adopters vs non-adopters**

(₹ / ha)

| Particulars | Bihar | | Haryana | | Punjab | | Uttar Pradesh | |
|---|---|---|---|---|---|---|---|---|
| | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters |
| Human and mechanical labour | 4272 (-14.68) | 5007 | 4532 (-21.07) | 5742 | 4310 (-23.01) | 5598 | 3963 (-16.76) | 4761 |
| Seed | 1596 (-2.74) | 1641 | 1902 (-6.65) | 2038 | 1797 (-6.26) | 1917 | 1508 (-5.51) | 1596 |
| FYM | 850 (8.97) | 780 | 810 (6.30) | 762 | 838 (11.73) | 750 | 601 (14.48) | 525 |
| Plant nutrients | 2502 (-3.62) | 2596 | 2781 (-4.43) | 2910 | 2849 (-5.35) | 3010 | 2369 (-9.82) | 2627 |
| Irrigation | 1318 (-8.28) | 1437 | 1342 (-12.00) | 1525 | 1655 (-12.80) | 1898 | 2462 (-10.37) | 2747 |
| Weed control | 1098 (-20.32) | 1378 | 1416 (-6.04) | 1507 | 1801 (-9.54) | 1991 | 916 (-21.24) | 1163 |
| Plant protection cost | 998 (-27.89) | 1384 | 1540 (-29.49) | 2184 | 1393 (-36.57) | 2196 | 1023 (-19.39) | 1269 |
| Total input cost | 12634 (-11.17) | 14223 | 14323 (-14.07) | 16668 | 14643 (-15.65) | 17360 | 12842 (-12.57) | 14688 |

*Note:* Figures with negative sign within parentheses indicate the percentage input cost saving by RCT adopters over non-adopters in respective states, while non-negative figures indicate additional percentage cost.

**Table 5. Input saving in wheat cultivation by RCT adopters over non-adopters in IGP region**

| Particulars | Bihar | Haryana | Punjab | Uttar Pradesh |
|---|---|---|---|---|
| Ploughing (No.) | -100 | -100 | -100 | -100 |
| Land levelling (No.) | -100 | -100 | -100 | -100 |
| Harrowing (No.) | -100 | -100 | -100 | -100 |
| Hand weeding (No.) | -28.13 | -15.38 | -20.00 | -23.91 |
| Human and mechanical labour (hours) | -24.35 | -26.50 | -20.81 | -22.31 |
| Seed (kg) | -6.55 | -6.13 | -6.25 | -5.49 |
| FYM (quintals) | 10.58 | 6.30 | 18.50 | 10.89 |
| Urea (kg) | -7.75 | -7.96 | -3.08 | -8.14 |
| DAP (kg) | -7.85 | -8.82 | -12.10 | -12.50 |
| MOP (kg) | -13.37 | 0.00 | 0.00 | -5.28 |
| Other fertilisers (kg) | -3.81 | -11.56 | -19.61 | -5.35 |
| Plant nutrients (chemicals, kg) | -8.06 | -8.28 | -6.02 | -8.90 |
| Irrigation (No.) | -10.40 | -5.82 | -9.38 | -6.77 |
| Total plant protection (kg) | -31.06 | -23.31 | -14.43 | -29.17 |

*Note:* Negative sign indicates saving of RCT adopters over non-adopters.

The distribution of technical, allocative and economic efficiencies of farms under various efficiency class intervals has been depicted in Table 8. The overall figures of technical efficiency show that a maximum of 36.8 per cent of the adopter farmers were under the efficiency class of 80-90 per cent and 23.8 per cent were under the efficiency class of 90-100 per cent as against 25.2 per cent and 12.4 per cent in case of non-adopters. In the case of non-adopters, a considerable number (13.6%) of farmers fell under the category of 50-60 per cent efficiency, and there were some (40%) even under the category of < 50 per cent efficiency level.

**Table 6. Differential in cost, yield and returns from wheat cultivation in Indo-Gangetic Plains — Adopters vs non-adopters**

(per hectare)

| Particulars | Bihar | | Haryana | | Punjab | | Uttar Pradesh | |
|---|---|---|---|---|---|---|---|---|
| | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters | Adopters | Non-adopters |
| Total input cost (₹) | 12634 | 14223 | 14323 | 16668 | 14643 | 17360 | 12842 | 14688 |
| | (-11.17) | | (-14.07) | | (-15.65) | | (-12.57) | |
| Grain yield (tonnes) | 2.84 | 2.79 | 4.30 | 4.11 | 4.94 | 4.56 | 2.95 | 2.89 |
| | (1.79) | | (4.62) | | (8.33) | | (2.08) | |
| By-product yield | 2.82 | 2.75 | 3.19 | 3.09 | 3.22 | 2.80 | 2.51 | 2.38 |
| (tonnes) | (2.55) | | (3.24) | | (15.00) | | (5.46) | |
| Grain price (₹) | 638.33 | 631.57 | 624 | 617.30 | 630 | 630 | 625 | 623 |
| | (1.07) | | (1.10) | | (0.00) | | (0.32) | |
| Grain revenue (₹) | 18129 | 17621 | 26836 | 25371 | 31122 | 28728 | 18438 | 18005 |
| | (2.88) | | (5.78) | | (8.33) | | (2.40) | |
| By-product revenue (₹) | 3074 | 3031 | 3780 | 3492 | 3542 | 3158 | 2812 | 2797 |
| | (1.43) | | (8.26) | | (12.15) | | (0.57) | |
| Total returns (₹) | 21202 | 20651 | 30616 | 28863 | 34664 | 31886 | 21250 | 20801 |
| | (2.67) | | (6.08) | | (8.71) | | (2.16) | |
| Return over cost (₹) | 8568 | 6428 | 16293 | 12195 | 20021 | 14526 | 8408 | 6113 |
| | (33.29) | | (33.60) | | (37.82) | | (37.54) | |
| Return/cost | 1.68 | 1.45 | 2.14 | 1.73 | 2.37 | 1.84 | 1.65 | 1.42 |
| | (15.58) | | (23.44) | | (28.88) | | (16.84) | |

*Note:* Figures within parentheses indicate the percentage change in particulars experienced by adopters over non-adopters in respective states.

**Table 7. Economic efficiencies of adopters and non-adopters in IGP region**

(per cent)

| State | Adopters | | | Non-adopters | | |
|---|---|---|---|---|---|---|
| | Technical efficiency | Allocative efficiency | Economic efficiency | Technical efficiency | Allocative efficiency | Economic efficiency |
| Punjab | 89 | 94 | 83 | 87 | 93 | 81 |
| Haryana | 82 | 95 | 78 | 76 | 82 | 62 |
| Uttar Pradesh | 75 | 91 | 68 | 72 | 91 | 66 |
| Bihar | 77 | 90 | 69 | 65 | 90 | 58 |

Around 93 per cent of RCT-adopter farms had more than 80 per cent allocative efficiency and 62 per cent had more than 90 per cent allocative efficiency in contrast to 85 per cent and 43 per cent of non-adopter farms in these efficiency levels. The state-wise analysis indicated that more than 90 per cent of the adopter farms had more than 90 per cent allocative efficiency in both Punjab and Haryana. In the case of non-adopters, only 52 per cent farmers of Punjab and 26 per cent farmers of Haryana had allocative efficiency of more than 90 per cent. In terms of economic efficiency, around 65 per cent of the adopters were operating under more than 70 per cent economic efficiency category, while the percentage of such non-adopters was only 36 per cent. A substantial number (> 10%) of non-adopters was operating even under less than 50 per cent efficiency class. In general, the percentage of RCT-adopter farmers was much higher in higher efficiency class intervals and that of non-adopters was higher in lower efficiency class intervals.

**Table 8. Distribution of farmers across different efficiency classes in the study domain**

| Efficiency class (%) | Adopters | | | | | Non-adopters | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Punjab | Haryana | Uttar Pradesh | Bihar | Overall | Punjab | Haryana | Uttar Pradesh | Bihar | Overall |
| **Technical efficiency** | | | | | | | | | | |
| < 50 | - | - | - | - | - | - | 12.0 | 2.0 | 6.0 | 4.0 |
| 50-60 | - | - | 7.0 | 6.0 | 2.6 | - | 22.0 | 12.0 | 34.0 | 13.6 |
| 60-70 | - | 5.0 | 29.0 | 22.0 | 11.2 | 2.0 | 24.0 | 34.0 | 32.0 | 21.2 |
| 70-80 | 12.0 | 34.0 | 31.0 | 39.0 | 25.6 | 14.0 | 28.0 | 28.0 | 20.0 | 23.6 |
| 80-90 | 44.0 | 44.0 | 24.0 | 20.0 | 36.8 | 62.0 | 12.0 | 18.0 | 4.0 | 25.2 |
| 90-100 | 44.0 | 17.0 | 9.0 | 13.0 | 23.8 | 22.0 | 2.0 | 6.0 | 4.0 | 12.4 |
| **Allocative efficiency** | | | | | | | | | | |
| < 60 | - | - | - | - | - | - | - | - | - | - |
| 60-70 | - | - | - | - | - | - | 6.0 | - | - | 1.2 |
| 70-80 | - | - | - | 13.0 | 6.6 | - | 36.0 | 4.0 | 16.0 | 14.0 |
| 80-90 | 10.0 | 9.0 | 46.0 | 34.0 | 31.4 | 48.0 | 32.0 | 22.0 | 22.0 | 42.0 |
| 90-100 | 90.0 | 91.0 | 54.0 | 53.0 | 62.0 | 52.0 | 26.0 | 74.0 | 62.0 | 42.8 |
| **Economic efficiency** | | | | | | | | | | |
| < 50 | - | - | 3.0 | 1.0 | 0.8 | - | 28.0 | 6.0 | 18.0 | 10.4 |
| 50-60 | - | - | 20.0 | 17.0 | 7.4 | - | 52.0 | 24.0 | 42.0 | 26.8 |
| 60-70 | 4.0 | 18.0 | 41.0 | 44.0 | 26.6 | 10.0 | 16.0 | 34.0 | 36.0 | 26.4 |
| 70-80 | 31.0 | 50.0 | 22.0 | 24.0 | 35.2 | 64.0 | 4.0 | 28.0 | 4.0 | 25.6 |
| 80-90 | 46.0 | 19.0 | 12.0 | 7.0 | 21.2 | 22.0 | - | 6.0 | - | 9.6 |
| 90-100 | 19.0 | 13.0 | 2.0 | 7.0 | 8.8 | 4.0 | - | 2.0 | - | 1.2 |

## Determinants of Adoption of RCT using Logit Model

The estimates of the logit model, which was used to find the impact of explanatory variables in the binary dependant variable, have been depicted in Table 9. To give a more precise explanation, odds ratio of point estimate of the factors influencing adoption was also worked out (Table 10).

The parameter estimates of all the equations were found negative in the case of age, farm family workers and source of knowledge, indicating that these factors adversely affect the adoption of technology. The odds ratio of the coefficient age of a farmer was 0.9802, indicating that RCT-adoption was favoured by the farmers of younger age. Education also favoured adoption of RCT in all the states; with every increase in the level of education, overall adoption increased by log of 0.216. A higher value of odds ratio for Bihar (2.134) indicated that the impact of education in favour of RCT-adoption was higher in Bihar than in other states, it was mainly because Bihar has a lower literacy level.

The negative signs for the logit coefficients and less than unit values of odds ratio indicated that the number of farm family workers adversely affected adoption of RCT, which indicated that RCT is a labour-conserving technology. Less than unit value of odds ratio (0.822) reflected that it did not favour adoption or the lesser availability of workers in the form of farm family workers favoured adoption. State-wise study of logit model also showed similar results. The regression coefficient for farm family workers in Bihar was -0.596, which is higher than that of other states, indicating that unit increase in farm family workers in this state would lead to lesser adoption of RCT.

The parameter estimate of the overall regression model for total cropped area irrigated was 0.020. Its coefficient has been found highest for Bihar (0.147), followed by Uttar Pradesh (0.102). This shows that with average increase in the size of operational holding by one hectare, there would be a rise in RCT-adoption by log of 0.147 in Bihar and by log of 0.102 in Uttar Pradesh. With more than unit value of odds ratio in all the states as well as at overall level has shown that the odds in favour of RCT-adoption increase with every unit increase in total irrigated cropped area.

Formal source of knowledge had a positive impact on RCT-adoption, as can be seen from the negative

**Table 9. Factors influencing RCT adoption in wheat cultivation in four selected states**

| Variable | Punjab | Haryana | Uttar Pradesh | Bihar | Overall |
|---|---|---|---|---|---|
| Age | -0.042* | -0.048** | -0.039*** | -0.107** | -0.020** |
| | (0.024) | (0.023) | (0.015) | (0.047) | (0.009) |
| Education level | 0.521*** | 0.534** | 0.432* | 0.758** | 0.216** |
| | (0.224) | (0.241) | (0.235) | (0.334) | (0.098) |
| No. of farm family workers | -0.496** | -0.461* | -0.421** | -0.596* | -0.196** |
| | (0.241) | (0.264) | (0.207) | (0.342) | (0.099) |
| Total cropped area irrigated | 0.056*** | 0.067*** | 0.102*** | 0.147*** | 0.020* |
| | (0.022) | (0.028) | (0.054) | (0.063) | (0.011) |
| Source of knowledge | -1.789** | -2.356** | -1.234** | -1.994** | -0.638*** |
| | (0.853) | (1.068) | (0.450) | (0.917) | (0.233) |
| Ownership of tractors | 0.124* | 0.266** | 0.165 | 0.325 | 0.257** |
| | (0.071) | (0.127) | (0.163) | (0.243) | (0.116) |
| Net returns | 1.340* | 1.435*** | 1.050* | 1.536** | 0.546*** |
| | (0.788) | (0.567) | (0.537) | (0.718) | (0.228) |
| Chi square | 16.916 | 8.081 | 5.764 | 11.656 | 13.135 |
| Correct prediction (%) | 80.7 | 79.3 | 73.3 | 89.2 | 78.1 |

*Notes:* ***, ** and * indicate significance at 1 per cent, 5 per cent and 10 per cent levels, respectively.
Figures within the parentheses are standard errors of the estimates

**Table 10. Point estimates of odds ratio for the factors influencing adoption of RCT in four selected states**

| Particulars | Punjab | Haryana | Uttar Pradesh | Bihar | Overall |
|---|---|---|---|---|---|
| Age | 0.958 | 0.953 | 0.961 | 0.898 | 0.980 |
| Education level | 1.683 | 1.705 | 1.540 | 2.134 | 1.241 |
| No. of farm family workers | 0.608 | 0.630 | 0.656 | 0.551 | 0.822 |
| Total cropped area (irrigated) | 1.057 | 1.069 | 1.107 | 1.158 | 1.019 |
| Source of knowledge | 0.167 | 0.094 | 0.291 | 0.136 | 0.528 |
| No. of tractors | 1.132 | 1.304 | 1.179 | 1.384 | 1.293 |
| Net returns | 3.819 | 4.199 | 2.857 | 4.645 | 1.726 |

sign of the parameter estimates for informal source of knowledge. The less than unit value of the odds ratio also indicated that informal source of knowledge disfavours adoption or conversely, the farmers rely more on formal source of information when it comes to adopting a new technology.

Possession of a tractor, not a necessary attribute, also favours adoption. On account of wider prevalence of custom hiring, the variable seems to contribute in favour of adoption. In the overall model, the parameter estimate of logit model for possession of tractor was 0.257, which indicated that with every increase in number of tractor possessed by the farmers, the adoption of RCT increases by antilog of 0.257. More than unit value of odds ratio in all the states has shown that with increase in number of tractors, the odds in favour of adoption also increase.

Both parameter estimates as well as odds ratio for net returns have indicated that net returns were the most important and decisive factor influencing RCT-adoption. The parameter estimate and odds ratio of net returns for the overall logit model were 0.546 and 1.726, respectively. The odds ratio was more than unit value indicating that economic returns or profitability was the most important driver to RCT-adoption. In Bihar, for every unit increase in net returns, the odds in favour of adoption increased by 4.645.

It can be concluded that education and net returns have a positive influence on adoption of RCT and the negative sign of parameter estimates of farm family worker indicates that more number of farm family workers disfavours adoption.

## Conclusions and Policy Implications

The comparative study on adopters and non-adopters of 'Resource Conservation Technologies' in the rice-wheat cropping system has clearly indicated the superiority of RCT over conventional practices in terms of cost saving and more efficient use of inputs. In order to enhance the productivity, profitability and sustainability of rice-wheat cropping system, the tillage technologies developed at the research farms need to be transferred and fine-tuned at farmer's field through on-farm participatory research. The study has suggested following policy implications for equitable and sustainable growth in adoption of these technologies:

- Since RCTs provide saving in input-cost, wide publicity including field demonstrations could generate awareness among the farmers about savings in sowing time and other costs in crop production.
- Since zero tillage and bed planting are the major drift from conventional tillage practices, a holistic approach with a completely new set of package of practices need to be evolved, evaluated and popularized.
- New soil, water and nutrient management practices need to be tailored to understand the dynamics of changed physical, chemical and biological properties of soil as a result of RCT- adoption.
- There is a need to bring researchers, extension workers and farmers on a common platform to conceive end-to-end strategies to promote RCTs.
- Extending adoption of RCTs from crop-based approach to system approach would further bring about a sea change in their adoption in the entire IGP transect, thereby meeting the food requirements by sustained growth in productivity.
- Saving of energy from less tillage and reduced irrigation has strategic benefit for the country as a whole. Thus, wider adoption of RCTs has long-run ramifications in terms of conserving natural resources, saving cost on cultivation and improving the climatic conditions in the region.

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## References

Coelli, T.J. (1994) *A Guide to FRONTIER Version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation* (mimeo), Department of Econometrics, University of New England, Armidale.

Coelli, T.J. (1996) *A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program*, Department of Econometrics, University of New England, Armidale.

Gupta, R.K., Singh, Sammar, Malik, R.K., Singh, Govindra, Naresh, R.K., Mehla, R.S., Sidhu, B.S., Brar, S.S., Sah, G., Tripathi, J., Prabhakar, S.V.R.K., Sharma, R.K., Singh, S.S., Singh, C.M., Kumar, M., Singh, U.P., Bhushan, L., Hobbs, P.R., Ladha, J.K. and Singh, B.K. (2003) *Zero-Tillage in Rice-Wheat Systems: Frequently Asked Questions*. Technical Bulletin No. 6, Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi-110 012, 28 p.

Kumar, A. and Yadav, D.S. (1993) Effect of long-term fertilization on soil fertility and yield of rice–wheat cropping system. *Journal of the Indian Society of Soil Science*, **41**: 178-180.

Lal, Rattan, Hansen, David O., Hobbs, Peter R. and Uphoff, Norman (2004) *Sustainable Agriculture and the International Rice-Wheat System* (mimeo) pp. 495-512.

Mehla, R.S., Verma, J.K., Gupta, R.K. and Hobbs, P.R. (2000) *Stagnation in the Productivity of Wheat in the Indo-Gangetic Plains: Zero-till-seed-cum-fertilizer Drill as an Integrated Solution*. Consortium Paper Series 8. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, 12p.

Narang, R. S. and Virmani, S. M. (2001) *Rice Wheat Cropping Systems of the Indo-Gangetic Plain of India*. Consortium Paper Series 11. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, 1p.

Swarup, A. and Singh, K. N. (1989) Effect of 12 years rice–wheat cropping and fertilizer use on soil properties and crop yields in a sodic soil. *Field Crops Research*, **21**: 277-287.

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