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Revitalizing the Rice-Wheat Cropping Systems of the Indo-Gangetic Plains: Adaptation and Adoption of Resource-Conserving Technologies in India, Bangladesh, and Nepal

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EXECUTIVE SUMMARY

The rice-wheat (RW) cropping system of the Indo-Gangetic Plains (IGP) in South Asia is vital for food security and livelihood for millions of rural and urban people. This system is practiced on more than 13.5 million hectares in South Asia. Now, the productivity and sustainability of the RW system are threatened because of a) the inefficient use of inputs (fertilizer, water, labor); b) increasing scarcity of resources, especially water and labor; c) changing climate; and d) socioeconomic changes (urbanization, labor migration, preference of nonagricultural work, concerns about farm-related pollution, etc.). Therefore, there is a need for appropriate resource-conserving technologies (RCTs) to overcome these emerging constraints and to enhance system productivity, input-use efficiency, and farm profitability on a sustainable basis. To achieve some of these objectives, a USAID-funded project was implemented during 2007-08 in three IGP countries (India, Nepal, and Bangladesh) with the following objectives: 1) to accelerate RCT adoption in key areas of South Asia to overcome yield stagnation, increase input-use efficiency, reduce the cost of cultivation, and improve system sustainability through a series of local hubs that integrate public- and private-sector research and extension, and (2) to design, test, and perfect minimum-till rice-wheat production systems that are efficient in labor, water, energy, and N use, building on experience with direct-seeded rice and zero-till wheat in other parts of the IGP.

To achieve project objectives, different RCTs in rice and wheat were refined and validated and their benefits were demonstrated in about 14,000 on-farm trials in a farmers' participatory approach at 11 sites of five hubs in three IGP countries. Training activities and educational programs were organized for various stakeholders—farmers, extension workers, researchers, service providers, private machine manufacturers, and policymakers—to accelerate the adoption of RCTs in the region. A total of 64 training sessions were organized and 4,357 participants were trained, including 2,646 farmers. To promote RCTs, dissemination and promotional activities such as television (16) and radio (2) programs, popular articles (> 25), and visits of policymakers and scientists (28) were also undertaken.

All the proven RCTs (zero-till, bed planting, surface seeding, reduced-till) in wheat performed better than the farmers' practice (CT-BCW). Gains in grain yield with the RCTs over the farmers' practice were 1.0 to 1.9, 0.09 to 1.5, and 0.6 to 1.0 t/ha when wheat was planted on beds, using zero-till, and using reduced-till, respectively, and income gain ranged from US$81 to $240/ha. Surface-seeded wheat (ZT-BCW) in areas with high soil moisture did not increase grain yield compared with CT-BCW but did increase farmers' income. In addition to wheat, benefits of ZT were also documented in other rabi crops. Lentil, fababean, gram, lathyrus, mustard, and coriander performed better in ZT than in conventional tillage in terms of yield and net income. Laser land leveling (LLL) reduced water application up to 40%. Savings in irrigation cost from LLL

over traditional leveling varied from $11 to $32/ha in rice, from $14 to $44/ha in wheat, from $14 to $35/ha in maize, and from $27 to $32/ha in potato. Other benefits of LLL were improved crop stand, input-use efficiency, and crop productivity.

Successful RCTs for rice include LLL, integrated crop and resource management (CT-TPR-ICRM), and LCC-based precision N management. The yield gain by adopting CT-TPR-ICRM was 0.75 to 1.0 t/ha. Other RCTs of rice evaluated, validated, and fine-tuned in farmers' fields were direct-seeded rice using ZT (ZT-DSR), reduced-till (RT) DSR, drum seeding (CT-DrumR), and transplanting in unpuddled fields on flat land (RT-TPR) and on beds (Bed-TPR). Co-culture of *Sesbania* with rice in ZT-DSR (ZT-DSR+Ses), also known as brown manuring, was found effective in suppressing weeds and improving soil quality and crop productivity. The performance of DSR in terms of productivity was variable, ranging from lower or similar yield compared with the farmers' practice to higher yield to the tune of 0.2 to 1.4 t/ha; however, in terms of net income, DSR was always superior to the farmers' practice. Hybrids performed better than commonly grown varieties in the region under ZT-DSR. This suggests that direct seeding has potential to substitute for puddled transplanting but needs more refinement. The major constraints to the success of DSR were weed control and precise water management at crop establishment. A few trials failed mainly because of continuous rain immediately after sowing of rice.

There is a lot of scope for diversification/intensification of the present system by using a pigeon pea variety with extra short duration, inclusion of a third crop between rice and wheat (e.g., short-duration summer mungbean), and by intercropping using a furrow-irrigated raised-bed system (potato + maize, potato + sugarcane, maize + pea, and sugarcane + mentha). These diversified systems have enhanced farmers' income by $115 to $1,890/ha.

Based on a randomly selected village survey in 2007-08, about 1.26 million ha of wheat are under zero-/reduced-till in Haryana and Indian Punjab. Survey results also showed that the adoption of other tillage systems (primarily rotavator) has increased markedly in these two states. A rotavator offsets much of the gain implied by more CA-based RCTs such as zero- or reduced tillage; therefore, urgent intervention is needed to reduce use of a rotavator. The survey results illustrate the regional variation in the diffusion of resource-conserving tillage and crop establishment methods in wheat. In the northwestern IGP, conventional tillage continues its downward trend, with farmers increasing their area of ZT and particularly other (rotavator) tillage, whereas reduced tillage is relatively constant. The trends in tillage and establishment systems in the central and eastern IGP were less clear, with a little over a third of the wheat area under ZT/RT in the central zone and more than 90% under conventional tillage in the eastern Gangetic Plains.

As part of facilitation and coordination activities, the RWC facilitated the implementation of numerous participatory research trials at many sites in four countries—India, Pakistan, Nepal, and Bangladesh. In addition, the RWC provided technical backstopping, organized workshops, training, and traveling seminars, and brought out many publications to enhance the impact of RCTs.

1. INTRODUCTION

1.1. Project Background

Rice and wheat are grown annually in sequence on more than 13.5 million hectares in the Indo-Gangetic Plains (IGP) of South Asia, where the rice-wheat (RW) rotation is vital for food security and livelihood for millions of rural and urban people. This cropping system so far has maintained the balance between food supply and population growth but recent evidence shows that productivity and sustainability of this system is threatened as yields of both rice and wheat are either stagnant or decreasing and total factor productivity is declining for the following reasons: 1) inefficiencies in the current production system; 2) increasing shortage of resources, especially water and labor; 3) changing climate; and 4) socioeconomic changes (such as urbanization, labor migration, preference of nonagricultural work, rapid economic growth led to increased labor requirement in nonagricultural sectors) (Ladha et al 2003). Therefore, the conventional production practices used in the region need to be improved or replaced by resource-conserving technologies (RCTs) to adapt to emerging changes and to enhance system productivity, input-use efficiency, and farm profitability on a sustainable basis (Ladha et al 2003).

Resource-conserving technologies (RCTs) such as zero-tillage (ZT), raised beds, and laser land leveling have been found beneficial in the western IGP in reducing cultivation cost and energy consumption and improving crop productivity, input-use efficiency, and farmers' income (Erenstein et al 2008, Gupta and Seth 2007). The success of RCTs has not been fully harnessed in the less-endowed region of the eastern IGP, although these technologies have potential in the eastern IGP. This project aimed at building capacity for fine-tuning and scaling out of proven technologies around five representative on-farm research hubs in the eastern IGP (Bihar, eastern Uttar Pradesh, the Terai of Nepal, and Bangladesh).

1.2. Goal and Objectives

The overall goal of the project was to reduce poverty, generate employment, improve system productivity and profitability, reduce production costs, foster system diversity, and improve water productivity by developing and fostering the dissemination of a wide variety of RCTs, especially direct-seeded rice with no or reduced tillage. Specific objectives were

1. To accelerate RCT adoption in key areas of South Asia to overcome yield stagnation, increase input-use efficiency, reduce the cost of cultivation, and improve system sustainability through a series of local hubs that integrate public- and private-sector research and extension.
2. To design, test, and perfect minimum-till rice-wheat production systems that are efficient in labor, water, energy, and N use, building on experience with direct-seeded rice and zero-till wheat in other parts of the IGP.

1.3 Project Activities

Activity 1: Adaptive research to fine-tune RCTs
Activity 2: Scaling out of proven RCTs

Activity 3: Documentation and enhancing impact
Activity 4: Facilitation and coordination

2. SUMMARY OF MAJOR ACTIVITIES

About 14,000 on-farm trials were conducted to evaluate different RCTs in rice and wheat at various hubs of three IGP countries during 2007 to 2008. Details of these different RCTs evaluated in farmers' field are given in Table 1. Farmers refined, validated, and selected the most suitable technologies for their regions by using their own criteria for selection. Another category of activities includes various types of training and educational programs organized for different stakeholders of the project—farmers, extension staff, researchers, local university personnel, service providers, private machine manufacturers, and policymakers. A total of 64 training and educational events were organized at four hubs in all three countries during the project period 2007-08, with an estimated total of 4,357 participants (Table 1). The categorized training activities included 16 training sessions to train 786 research and extension staff, 34 hands-on training activities on RCTs to train 2,646 farmers, 5 field days to demonstrate the benefits of RCTs to 278 farmers/policymakers, 6 workshops with 514 participants, and 3 traveling seminars with 133 participants. The third category included dissemination and promotion activities, including the use of extension materials. Sixteen television programs and two radio programs were developed (Table 1). Twenty-eight visits were organized for policymakers and scientists to the project sites. More than 25 popular articles and news items were published in different newspapers to popularize and to increase awareness of the RCTs in the region.

Table 1. Major project activities indicating number of events and participants/beneficiaries at different hubs during October 2007 to September 2008.[1]

Activity	No. of trials, events, and participants' activities					
	India			Nepal	Bangladesh	Total
	Bihar	Uttar Pradesh	West Bengal			
1. Validation and dissemination of RCTs						
Laser land leveling	38	0	–	–	–	*38*
CT-BCW	35	4,530	–	74	44	*4,683*
RT-DSW	–	69	–	–	–	*69*
Bed-DSW	29	3	–	–	–	*32*
ZT-DSW	1,066	4,530	–	74	44	*5,714*
ZT-DSW (PR)	284	0	–	–	–	*284*
ZT-DSW (TC)	43	0	–	–	–	*43*
ZT-DSW with residue (Happy Seeder)	41	3	–	–	–	*44*
ZT-BCW (SS)	18	0	–	–	–	*18*
DZT-DSW	30	5	–	–	–	*35*
ZT in other rabi crops	347	19	–	–	–	*366*
ZT in summer legume (mungbean)	32	0	–	–	–	*32*
Maize on beds	25	0	–	–	–	*25*
Maize + pea on beds	20	0	–	–	–	*20*
Peas on beds	6	0	–	–	–	*6*
CT-TPR	66	17	103	120	531	*837*
CT-TPR-ICM	–	–	–	120	531	*651*
CT-BCR	–	4	–	–	–	*4*
CT-DrumR	11	27	–	–	–	*38*
RT-DSR	3	20	–	–	–	*23*

Activity	No. of trials, events, and participants' activities					
	India			Nepal	Bangladesh	Total
	Bihar	Uttar Pradesh	West Bengal			
Bed-TPR	3	0	–	–	–	*3*
Bed-DSR	–	1	–	–	–	*1*
ZT-DSR	256	65	85	–	–	*406*
ZT-DSR+Ses	26	0	20	–	–	*46*
ZT-DSR-LCC	5	0	–	–	–	*5*
ZT-TPR	2	12	–	–	–	*14*
Intensification/diversification	96	10	–	–	20	*126*
Total on-farm RCTs	*2,482*	*9,315*	*208*	*388*	*1,170*	**13,563**
2. Training and capacity building						
Training for research and extension staff	13 (610)	2 (150)	–	1 (26)	–	*16 (786)*
Training for farmers	32 (2,516)	–	–	2 (130)	–	*34 (2,646)*
Field days	3 (148)	–	–	2 (130)	–	*5 (278)*
Workshops/meetings	1 (40)	2 (400)	–	3 (74)	–	*6 (514)*
Traveling seminars	1 (93)	–	–	2 (40)	–	*3 (133)*
Total	*50 (3,407)*	*4 (550)*	–	*10 (400)*	–	**64 (4,357)**
3. Technology dissemination and promotion						
Visits	20	8	–	–	–	28
TV programs	13	3	–	–	–	16
Newspaper/publicity	26	–	–	–	–	26
Radio programs	–	2	–	–	–	2
Total	59	13	–	–	–	72

[1] The abbreviations of various RCTs used are given in Table 3.

3. PROJECT ACCOMPLISHMENTS

3.1. Technology Refinement, Evaluation, and Validation (Activities 1 and 2)

3.1.1. Laser land leveling

The lack of proper land leveling of fields is a concern in the eastern Gangetic Plains, where fields are uneven and irrigation water is lifted mainly by diesel-operated pumps. Traditionally, leveling is done by tractor-drawn levelers/boards or by bullocks using wooden planks, wherein, even after the best efforts and heavy investments, 8–15-cm deviation in field level exists, which leads to poor yields, low water productivity, and poor profitability. Keeping in view the importance of precise land leveling, 38 on-farm trials were conducted in Bihar to evaluate the potential benefits of laser land leveling for water savings and enhancing crop productivity. In these trials, savings in irrigation cost in different crops were monitored. Laser land leveling saved irrigation water up to 40%. The time required irrigating 1 hectare of land decreased from 28 hours in unleveled fields to 12–18 hours in laser-leveled fields. This translates into savings in irrigation water use of $20. Crop-wise analysis showed that savings in irrigation cost under laser leveling compared with traditional leveling ranged from $11 to $32/ha in rice, $14 to $44/ha in wheat, $14 to $35/ha in maize, and $27 to $32/ha in potato. In addition, farmers also observed better germination and crop stand after precision land leveling that resulted in higher productivity.

3.1.2. Wheat with various RCTs

Proven RCTs [reduced-till (RT-DSW) and zero-till drill-seeded wheat (ZT-DSW), zero-till drill-seeded wheat (ZT-DSW) with residue mulch (using a Happy Seeder), broadcast wheat in high-moisture soil without any tillage (ZT-BCW), and bed-planted drill-seeded wheat (Bed-DSW)] for each hub were selected from the set of RCTs that have been developed over the past 10 years. Farmers evaluated these proven RCTs in wheat for yield, net income, cost of production, and resource use.

All the RCTs in wheat performed better than the farmers' practice [conventional-till broadcast wheat (CT-BCW)] (Table 2). The gain in grain yield (yield obtained with RCT – yield obtained from the farmers' practice) was highest when wheat was drill seeded on beds (Bed-DSW), ranging from 1.0 to 1.9 t/ha, followed by ZT-DSW (0.09 to 1.5 t/ha), or RT-DSW (0.6 to 1.0 t/ha), and was lowest in surface-seeded wheat (ZT-BCW). ZT-DSW in the presence of previous crop residues using the Happy Seeder evaluated at two sites in Ballia, Uttar Pradesh, and in Jamui, Bihar, provided a yield advantage of 0.3 and 1.5 t/ha, respectively.

Although no additional gain in yield in surface-seeded wheat (ZT-BCW) was found over the farmers' practice (CT-BCW), it provided an additional gain in income of $240 because of savings in tillage costs (Table 2). Though it provided the highest gain in grain yield, the income gain of bed-planted wheat (Bed-DSW) was similar to that of ZT-DSW ($166–174/ha). ZT-DSW also provided savings in tillage and seed cost of $36 and $13/ha, respectively (Fig. 1). Irrigation water savings ranging from 13% to 33% are another feature of ZT. Water savings of 30–50% in bed-planted wheat have been reported. In addition, ZT provided fuel savings (75%) over CT-BCW.

The increases in wheat yield in Bed-DSW and ZT-DSW were likely due in part to timely sowing of the crop and band placement of fertilizer. Previous studies have also shown higher wheat yield in ZT and raised beds. Although yield in surface-seeded wheat was lowest compared with other RCTs and was equivalent to CT-BCW, it provided additional income gains to farmers from the excessively wet fields in which surface seeding is the only option. If farmers wait until soil becomes workable, it will be too late for wheat planting and thus land will remain fallow.

Table 2. Average change in wheat productivity and net income with various RCTs during *rabi* 2007-08.[1]

Hubs	Yield gain over farmers' practice (t/ha (US$/ha[2]))				
	RT-DSW	ZT-DSW	ZT-DSW (Happy Seeder)	ZT-BCW (SS)	Bed-DSW
Eastern Uttar Pradesh					
NDUAT, Faizabad	–	0.09	–	–	–
BHU, Banaras	0.60	0.41 (174)[3]	0.30 (81)	–	1.00 (173)
Bihar					
ICAR-RCER, Patna	–	0.28 (167)[3]	–	0.06 (240)	–
KVK, Jamui	–	1.11	1.50	–	1.90
DMR, Begusarai	–	0.32	–	–	1.14 (166)
Nepal (NWR-Bhairahawa)	0.8[4]	–	–	–	–
Bangladesh	1.0[4]	–	–	–	–

[1] The abbreviations for different RCTs used are given in Table 3.

[2] Numbers in parentheses are changes in net income

[3] Average of different versions of ZT options such as ZT-DSW (TC), ZT-DSW (PR), and DZT-DSW.

[4]In Nepal and Bangladesh, it was reduced-till drill-seeded wheat using a PTOS (power-tiller-operated seeder) (RT-DSW-PTOS).

– = not applicable.

Table 3. Abbreviations and brief descriptions of conventional technologies and RCTs for rice and wheat.

Series no.	Abbreviation	Brief description/explanation
Rice		
1	CT-TPR	Conventional-till (puddled) transplanted rice
3	CT-DrumR	Conventional-till (puddled) drum-seeded rice
4	RT-TPR	Reduced-till (2–4 passes but unpuddled) transplanted rice
5	RT-DSR	Reduced-till (2–4 passes but unpuddled) drill-seeded rice
8	Bed-DSR	Raised-bed drill-seeded rice
9	Bed-TPR	Raised-bed transplanted rice
11	ZT-DSR	Zero-till drill-seeded rice
13	ZT-DSR+Ses	Zero-till drill-seeded rice with *Sesbania* co-culture
14	ZT-DSR-LCC	Zero-till drill-seeded rice and nitrogen management using leaf color chart
Wheat		
1	CT-BCW	Conventional-till broadcast wheat
2	RT-DSW	Reduced-till drill-seeded wheat
3	RT-DSW (PTOS)	Reduced-till drill-seeded wheat (power-tiller-operated seeder)
5	Bed-DSW	Raised-bed drill-seeded wheat
6	ZT-BCW	Zero-till broadcast (surface-seeded) wheat
7	ZT-DSW	Zero-till drill-seeded wheat
8	ZT-DSW (PR)	Zero-till drill-seeded wheat in paired row
9	ZT-DSW (TC)	Zero-till drill-seeded wheat with traffic control
10	DZT-DSW	Double zero-till drill-seeded wheat (both rice and wheat)

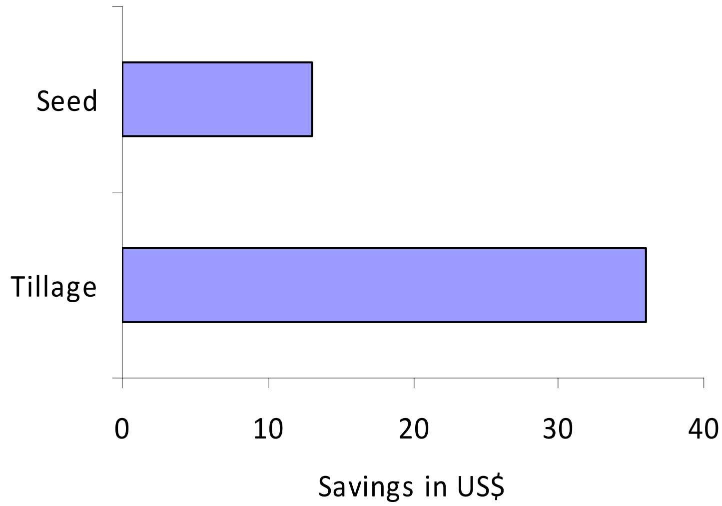

Fig. 1. Savings in tillage and seed cost by using ZT in wheat compared with farmers' practice (CT-BCW).

The higher net income in bed-planted wheat was due to a combined gain from yield increases and savings in irrigation costs, whereas, in ZT wheat, it was a combination of yield gain and reduced production costs (savings in tillage, seeds, and irrigation costs).

3.1.3. Rice with various RCTs

Adaptive research in farmers' fields was conducted to fine-tune RCTs in rice. Special emphasis was given to designing, testing, and perfecting year-round minimum-till rice-wheat production systems that are efficient in labor, water, energy, and N use and that maintain some degree of soil cover. The performance of different RCTs tested during the rice season is given below:

i) Drum seeding of rice on puddled soil (CT-DrumR): Compared with the farmers' practice (CT-TPR), the yield advantage and additional income due to drum seeding (CT-DrumR) were variable, ranging from lower or similar yield to higher yield of 0.5 t/ha depending on the site (Table 4). The high variability in performance of drum-seeded rice could be due to variable farmers' skills in mastering the technology and related practices such as land leveling, water control for the first 10–15 days, and weed management. Therefore, drum-seeding technology needs further work with farmers to improve and refine it before it is ready for dissemination.

ii) Tillage and crop establishment for rice in nonpuddled soil: In reduced-till unpuddled fields, both direct seeding and transplanting were more productive and profitable than CT-TPR (Table 4). Yield and income gain in reduced-till ranged from 0.14 to 1.1 t/ha and $48 to $231/ha, respectively. Transplanting of rice on raised beds in Jamui (Bihar) was also more productive (0.78 t/ha) than CT-TPR. The performance of zero-till direct-seeded rice

(ZT-DSR) was variable from site to site: a) in West Bengal (Coochbihar and Kolkata) and at Begusarai and Patna in Bihar, ZT-DSR yield was similar to that of CT-TPR; b) in Faizabad (eastern U.P.), yield was 0.45 t/ha lower; and c) in Pratapgarh and Banaras (eastern U.P.) and Jamui and Nawada (Bihar), ZT-DSR increased yield by 0.2 to 1.4 t/ha. Although the yield gain was variable in ZT-DSR, it provided higher net income than CT-TPR. The gain in net income ranged from $62 to $436. ZT-DSR with *Sesbania* (ZT-DSR+Ses), in which rice and *Sesbania* were sown together and then *Sesbania* was knocked down by spraying 2,4-D at 30–35 DAS, had a performance similar to that of ZT-DSR.

ZT-DSR reduces the cost of cultivation through savings in seeds, tillage, transplanting, and irrigation. The cost of weed control was higher in DSR than in CT-TPR. Total savings in production cost ranged from $100 to $131/ha. These results suggest that DSR is a potential technology for reducing production cost and enhancing productivity and profitability of farmers, but results are variable. Therefore, additional research is needed to perfect direct drill-seeding technology for rice in nonpuddled soil.

<u>iii) Integrated crop and resource management (ICRM):</u> There is a need to evaluate the simple leaf color chart (LCC) technology for precision N management in rice and to integrate it with other crop management techniques in an integrated crop and resource management (ICMR) approach to improve productivity, profit, and product quality in rice. Crop need-based N management with the help of an LCC in ZT-DSR (ZT-DSR-LCC) has increased grain yield by 0.15 t/ha and net income by $127 compared with CT-TPR (Table 4). Similarly, ICRM for transplanted rice (CT-TPR-ICRM) in Nepal and Bangladesh increased grain yield by 0.75 to 1.1 t/ha and net income by $101/ha (Table 4). Thus, farmers can effectively reduce their yield gaps and enhance their farm income by adopting a full package of ICRM technologies in rice. The gain in income from ZT-DSR-LCC was a combined gain in yield and savings in production cost, including savings in fertilizer use. However, the gain in net income in CT-TPR-ICRM came primarily from a gain in yield and not from savings in production cost.

iv) Performance of hybrids under ZT-DSR and transplanted rice. An on-station trial was conducted to evaluate the performance of three hybrid varieties of rice, Arize 6444 (Proagro, Bayer), NK Sahadri (Syngenta), and PBH 71 (Pioneer), under direct seeding (zero-till) and puddled transplanting. A commonly grown inbred cultivar (MTU 1001) was also included for comparison. Hybrid varieties were more productive than commonly grown nonhybrids irrespective of tillage and crop establishment method (Table 5). Hybrid rice yielded higher when it was drill seeded in ZT than when transplanted in puddled soil. In contrast, the standard variety (MTU 1001) performed better under puddled transplanted conditions. The gain in grain yield and net income ranged from 0.2 to 1.2 t/ha and $54 to $216/ha, respectively, when hybrids were direct drill seeded rather than transplanted in puddled soil.

Table 4. Average change (RCT – farmers' practice) in rice productivity and net income with various RCTs during *kharif* 2008.

Hubs	Yield gain over farmers' practice (CT-TPR)							
	CT-TPR-ICRM[1]	CT-DrumR	RT-TPR	RT-DSR	Bed-TPR	ZT-DSR	ZT-DSR+Ses	ZT-DSR-LCC
	(t/ha (US$/ha[2]))							
Eastern Uttar Pradesh								
NDUAT, Faizabad	–	–0.6	–	–	–	–0.45	–	–
KVK, Pratapgarh	–	–	–	–	–	0.20	–	–
BHU, Banaras	–	0.50 (54)	0.14 (48)	1.1 (231)	–	1.4 (436)	–	–
Bihar								
ICAR, Patna	–	0.08 (75)	–	–	–	–0.03 (62)	–0.03 (65)	0.15 (127)
KVK, Jamui	–	–	–	–	0.78	0.85	0.74	–
DMR, Begusarai	–	–	–	–	–	0.00	–	–
KVK, Nawada	–	–	–	–	–	0.2 (169)	–	–
West Bengal								
UBKV, Coochbihar	–	–	–	–	–	0.06	–	–
DOA, Kolkata	–	–	–	–	–	0.00	–	–
Nepal	1.1	–	–	–	–	–	–	–
Bangladesh	0.75 (101)	–	–	–	–	–	–	–

[1] Abbreviations of various RCTs used are given in Table 3.

[2] Numbers in parentheses are the change in net income.

Table 5. Grain yield, input cost, and net income of different rice hybrids under zero-till direct seeding (ZT-DSR) and transplanting conditions (CT-TPR).

Variety	**Yield (t/ha)**		**Input cost (US$/ha)**		**Net income ($/ha)**	
	CT-TPR	**ZT-DSR**	**CT-TPR**	**ZT-DSR**	**CT-TPR**	**ZT-DSR**
Arize 6444	5.00	5.47	340	330	491	584
NK Sahadri	5.06	6.25	331	313	513	729
PBH-71	5.29	5.48	332	316	726	780
MTU-1001	4.44	3.90	293	234	447	414
Mean	4.95	5.27	324	298	544	627
$LSD_{.05}$	Tillage (T) = 0.10; variety (V) = 0.51; T*V = 0.72					

v) Disease and insect pest incidence in ZT-DSR and CT-TPR. To know the incidence of disease and insect pests with a shift from CT-TPR to direct-seeded rice, sheath blight and milibug incidence were evaluated in ZT-DSR and CT-TPR fields. The standard evaluation system developed by IRRI-Philippines (1996) was used for studying the scale of damage by these disease and insect pests. It was found that the effect of sheath blight was maximum, 23% in ZT-DSR in comparison with 61% in control fields. Infection of both sheath blight and milibug was lower in ZT-DSR than in CT-TPR (Fig. 2). The infection of sheath blight in CT-TPR was 56%, but only 14% in ZT-DSR. Similarly, the milibug infection rate declined from 26% in CT-TPR to 4% in ZT-DSR.

Fig. 2. Mean (±SE) percent infection rate of sheath blight and milibug under ZT-DSR and CT-TPR.

3.1.4. Crop diversification with new tillage and crop establishment methods

i) Integration of legumes

In the rice-wheat system of the eastern IGP, fields generally remain fallow for about 70–80 days between the harvest of wheat and planting of a subsequent rice crop. Efforts were made to introduce an additional short-duration crop of summer mungbean (60–65 days). Farmer participatory trials conducted with mungbean in Bihar yielded 0.78 to 1.45 t/ha (Table 6). Mungbeans also performed better under ZT (1.45 t/ha) than under conventional tillage (1.33 t/ha) and provided higher income ($745 versus $419) (Table 6). In Bihar, summer mungbean not only provided additional income but acted as a break crop and added some nitrogen through biological nitrogen fixation. Extra-short-duration pigeon pea (ESDP), cultivar ICPL 88039, was also evaluated in 27 farmers' fields in Patna and Buxar districts of Bihar as an option for diversification of the RW system. The average yield was 0.8 t/ha and it also allowed timely planting of a subsequent wheat crop.

Table 6. Grain yield and net income from short-duration summer mungbean with conventional tillage and zero-tillage in 2008.

Hub	Tillage	No. of farmers	Cultivar	Yield (t/ha)	Net income (US$/ha)
Bihar					
DMR, Begusarai[1]	Conventional	4	SML668	1.33	419
	Zero	30	SML668	1.45	745
ICAR, Patna[2]	Zero	8	Vishal	0.78	–

[1]Average of trials conducted in Muzzafarpur, East Champaran, Samastipur, Begusarai, and Vaishali districts of Bihar.

[2] Average of trials conducted in Patna and Buxur districts of Bihar.

ii) Potato and maize on furrow-irrigated raised beds (FIRB): Potato is an important cash crop in eastern Uttar Pradesh and north Bihar. Traditionally, farmers grow it as a sole crop or with maize intercropping immediately after potato planting or after earthing up of potatoes. Farmers' participatory trials were conducted in these two states on potato + maize intercropping by establishing a crop in November. Potato was planted on beds using a potato planter and maize in furrows. The introduction of a potato planter in these areas reduced the cost of planting by 40% and helped in timely and speedy planting. Timely labor availability at the peak planting time is becoming a major constraint to timely potato planting. The potato + maize system was more productive and remunerative (Table 7). Farmers, by adopting this system, obtained a regular yield of potato along with an additional crop of maize. Farmers received additional income of $144–501 by adopting potato + maize intercropping instead of the farmers' practice (potato sole crop).

Table 7. Yield and net returns of potato + maize intercrop and potato sole crop in eastern Uttar Pradesh and Bihar in 2007-08.[1]

Treatment	Bihar		Eastern Uttar Pradesh
	ICAR-Patna[2]	DMR, Begusarai[3]	BHU, Banaras
		t/ha (US$/ha)	
Potato (sole crop)	21.6	32.0 (1280)	25.7 (373)
Maize (sole crop)	4.1	–	–
Potato + maize	24.5 + 3.2	27.0 + 6.2 (1781)	24 + 1.9 (517)

[1] Numbers in parentheses are the change in net income.

[2] Cultivars used: potato (Kufari Ashoka); maize (QPM-Shaktiman 3)

[3] Cultivars used: potato (Kufari Badshah, K. Jyoti, K. Chamatkar); maize (900M).

iii) Potato and sugarcane on raised beds: Similar to maize + potato intercropping, the potato + sugarcane system evaluated in eastern Uttar Pradesh (in Ghazipur Village cluster) was more productive and remunerative than a traditional sole potato crop (Table 8). This intercropped system provided additional net income of $1,470.

Table 8. Yield and net returns of potato + sugarcane intercrop and sole potato crop in eastern Uttar Pradesh in 2007-08.

Treatments	Yield (t/ha)	Net income (US$/ha)
Potato (sole crop)	25.5	398
Potato + sugarcane	22.0 + 58.8	1,867

iv) Maize and pea on raised beds: In Jamui (Bihar), sole maize cultivation is common but returns are low. Therefore, 20 on-farm trials were conducted with a new cropping system (maize + pea) with the aim that this new cropping system would provide higher income with minor changes in input cost. Maize equivalent yield of the maize + pea system was 4.3 t/ha higher than maize only (Table 9). With this new cropping system, the cost of cultivation increased by only $115 and net income by $635.

Table 9. Yield, cost of cultivation, and net income of maize and maize + pea in Jamui (southeastern Bihar) in 2007-08.

Treatment	No. of farmers	Yield (t/ha)	Maize equivalent yield (t/ha)	Cultivation cost (US$/ha)	Net income ($/ha)
Maize	16	4.2	4.2	280	474
Maize + pea	20	3.8 + 1.85	8.5	395	1,109

v) Sugarcane and mentha intercropping: In Begusarai (Bihar), sugarcane is mostly planted as a sole crop in spring. To intensify the sugarcane production system, sugarcane and mentha (mint) intercropping was evaluated in a farmers' participatory trial to find out the feasibility of mentha intercropping in the region. Sugarcane cultivar BO 136 and mentha cultivar Kosi were planted simultaneously in loam soil during the last week of February in 2008. Sugarcane was planted 90 cm apart in rows and, in interrows, mentha was planted after planting cane with irrigation. The yield of sugarcane alone was 73 t/ha, whereas, when intercropped with mentha, sugarcane yielded 62.5 t/ha and mentha oil yielded 125 liters/ha. The mentha intercropping resulted in additional mid-season income of $1,890. It was also observed that weed and early shoot borer infestation was less in intercropped sugarcane than in a sole sugarcane crop.

vi) Wheat, maize, and cowpea on raised beds: Yield of wheat and maize + cowpea was higher under permanent beds than under conventional-till (Table 10). Wheat yield was 27% higher when planted on beds than with conventional tillage. Similarly, yield of cowpea + maize was 37% higher on beds than with a conventional-tillage system. In addition to a yield advantage, beds are known for water savings.

Table 10. Yield of wheat and maize + cowpea on permanent beds and conventional tillage.

Season	Crop	Variety	Yield (t/ha)	
			Raised beds	Conventional-till
Winter 2007	Wheat	HD2733	5.31	4.17
Spring 2008	Maize + cowpea	African tall	35.40	25.67

vii) Lentil after zero-tillage: ZT lentil was highly productive and profitable, with a yield increase of 0.33 t/ha (Jamui, Bihar) to 0.5 t/ha (Banaras, Uttar Pradesh) and net income from $337 to $386/ha (Fig. 3).

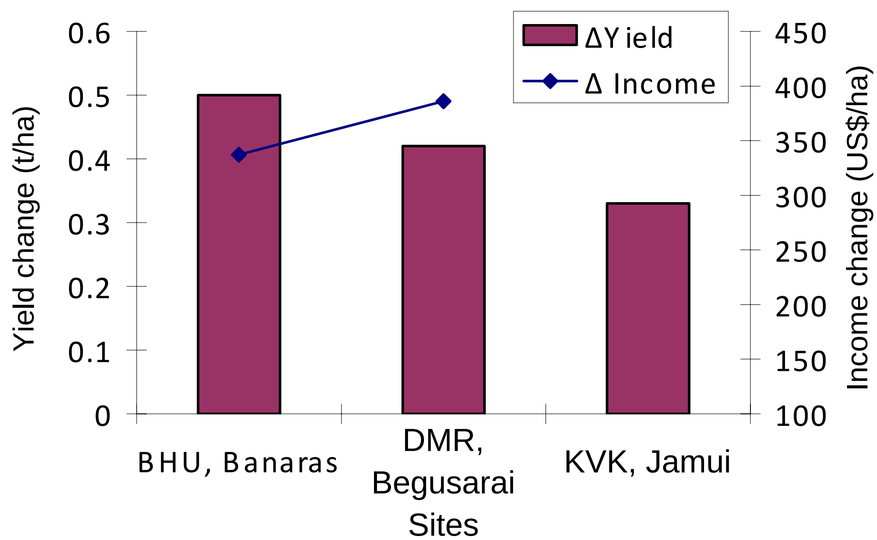

Fig. 3. Change in yield and net income with the use of ZT in lentil versus conventional-till.

viii) Faba beans after zero-tillage: The performance of faba bean (*Vicia faba*) under ZT was evaluated in Bihar (DMR, Begusarai). Faba bean is commonly planted in *chaurs* (a type of lowland depression in which water accumulates during the rainy season) during the winter season after intensive tillage. This crop gives good yield with little fertilizer and is generally grown as a rainfed crop. Mid-October to mid-November planting gives the best yield of faba bean. However, in *chaurs*, planting is delayed due to excessive soil moisture. To find out the feasibility of ZT faba beans, two farmer participatory trials were conducted in Kushmahot Village. Planting of faba bean was done using a multicrop ZT planter during the first week of November on silt clay soil. The crop was planted with a seed rate of 60 kg/ha. The average yield and net returns of faba bean were 3.12 t and $937/ha under zero-till, whereas, in conventional-till, yield and net returns were 2.56 t and $727/ ha, respectively.

ix) Gram, lathyrus, mustard, and coriander: All these crops performed better in ZT than in CT (Fig. 4). Coriander, lathyrus, mustard, and gram yielded 17%, 19%, 25%, and 27% higher, respectively, under ZT than under CT.

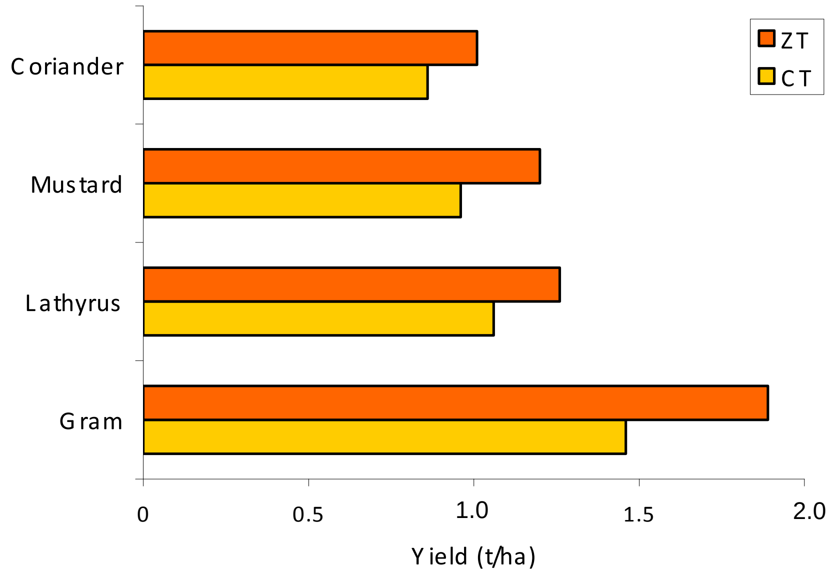

Fig. 4. Yield of coriander, mustard, lathyrus, and gram under ZT and CT in Jamui, Bihar.

3.2. Documenting and Enhancing Impact (Activity 3)

The two main activities during the time period revolved around new survey work and documenting and writing up past survey work.

3.2.1. New survey work

In the winter/rabi season of 2007-08, we revisited the same rice-wheat villages in Haryana surveyed earlier by Erenstein et al (2007b). These visits showed that ZT wheat area continued to increase, albeit at a slow pace, from an average share of village wheat area of 18% in 2004-05 to 24% in 2007-08 (Fig. 5). As reported earlier (Erenstein et al 2007b), reduced-till area in these villages was still marginal, with farmers using either zero-tillage or conventional tillage. Worryingly, however, there has been a rapid increase in another new tillage system (other tillage, OT), primarily using a tractor-drawn rotavator (Fig. 5). The rotavator typically uses a single pass of shallow intensive tillage, which incorporates crop residues and pulverizes the soil. It may be an RCT but it goes against conservation agriculture tenets (Erenstein 2009a).

In the winter/rabi season of 2007-08, we also conducted a wheat tillage monitoring survey across 120 randomly selected villages in Haryana and Indian Punjab. This study provided a more representative random sample of wheat-cultivating villages, and included non-rice-wheat systems. Compared to the Haryana rice-wheat study area (Fig. 5), the results showed some marked divergences (Fig. 6). First, the ZT area share is significantly lower—in both Haryana and Punjab—and it showed a small decline from 2005-06 to 2007-08. Second, the reduced-tillage (RT) area was a multiple of the ZT area and showed a small increase in both states. Extrapolating these estimates would imply a combined ZT/RT wheat area of 1.26 million ha in Haryana and Indian Punjab in 2007-08. The results also suggest that, after the initial rapid spread of ZT in the northwest IGP, the ZT/RT wheat area seems to have stabilized there between a fifth and a fourth of the wheat area. The study also shows that, particularly in Haryana (Fig. 6), and similar to the other study (Fig. 5), there was a marked increase in other tillage systems (primarily the rotavator). The advent of the rotavator merits follow-up research and active engagement with regional stakeholders as it offsets many of the gains implied by more CA-based RCTs such as ZT and RT (Erenstein 2009a).

Finally, the activity supported the implementation of the primarily ADB-funded village surveys in the winter/rabi season of 2007-08 across RWC research sites in South Asia in a total of 56 survey villages—19 control and 37 research villages. The recent evolution of wheat area under different tillage and establishment systems in survey villages illustrates the regional variation in RCT diffusion (Fig. 7). In the northwest IGP, conventional tillage continues its downward trend, with farmers increasing their area of ZT and particularly other (rotavator) tillage, whereas reduced tillage is relatively constant. The trends in tillage and establishment systems in the other two areas were less clear, albeit with a little over a third of the wheat area under ZT/RT in the central zone and more than 90% under conventional tillage in the eastern GP (Singh and Erenstein 2009).

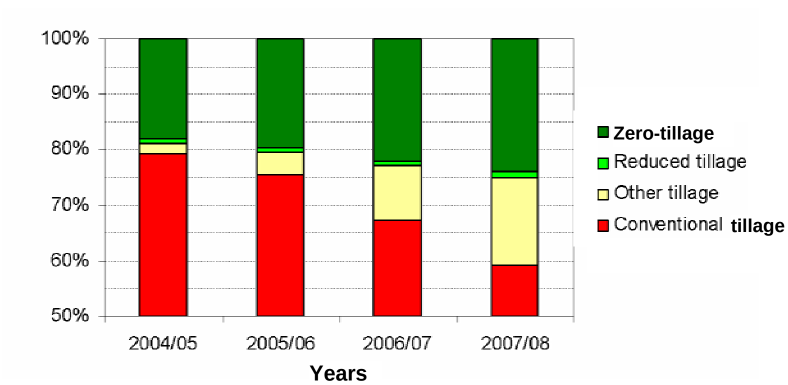

Fig. 5. Recent evolution of wheat tillage in the rice-wheat system in Haryana, India (village survey findings, n = 50). Source: Erenstein (2009a).

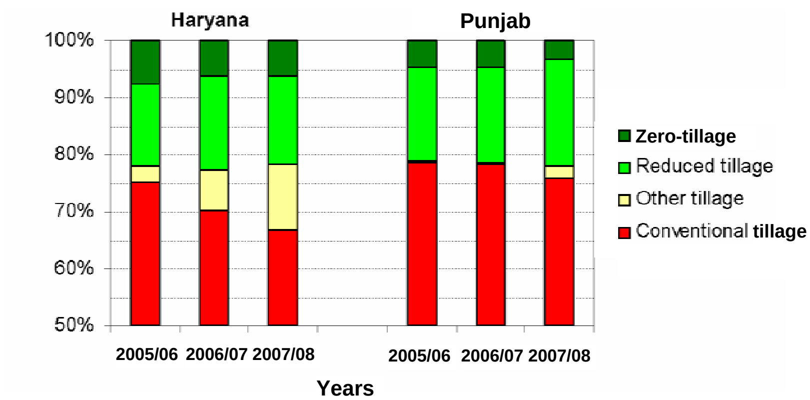

Fig. 6. **Recent evolution of wheat tillage systems in Haryana and Punjab, India (village survey findings, n = 120). Source: Erenstein (2009a).**

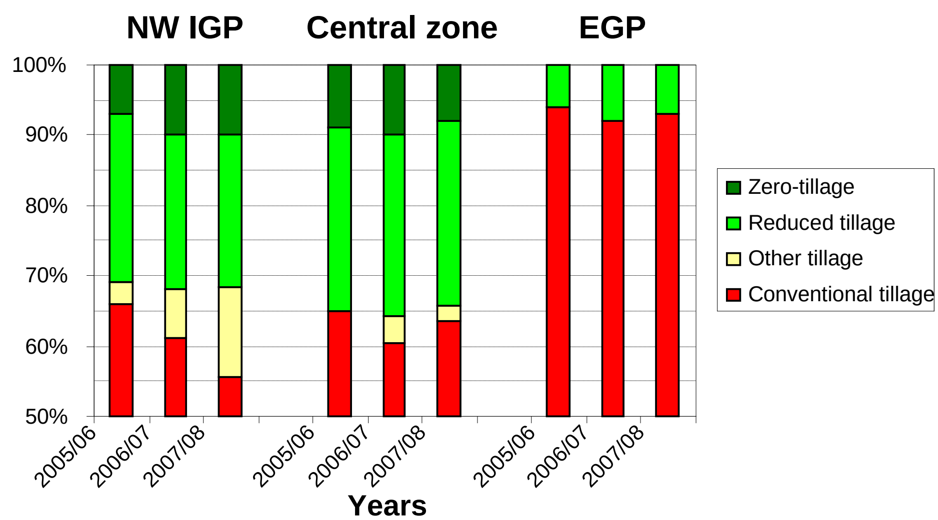

Fig. 7. Recent evolution of wheat tillage and establishment systems in survey villages (% of wheat village area, n ≥ 47) Source: Singh and Erenstein (2009).

3.2.2. Documenting and writing up past survey work

The external review of the Rice-Wheat Consortium (RWC) in 2004 recommended strengthening farm-level socioeconomic analysis (Seth et al 2003). In line with these recommendations, several studies were initiated over the past few years, including

- zero-tillage (ZT) adoption studies (Erenstein et al 2007b, Farooq et al 2007, a synthesis—Erenstein et al 2007a and derived papers—Erenstein and Laxmi 2008, Erenstein and Farooq 2009, Erenstein 2009b).
- a ZT impact assessment study (Laxmi et al 2007b and derived papers, Erenstein and Laxmi 2008, Laxmi et al 2007a).
- tillage monitoring surveys in the northwest IGP (Erenstein, 2009a).

- a study to assess the uptake and impacts of resource-conserving technology options (Singh and Erenstein 2009).
- initiatives to integrate the crop-livestock sector (Erenstein et al 2007d,e, Singh et al 2007, Teufel et al 2008, Thorpe et al 2007, Varma et al 2007) and promote crop diversification and intensification of rice-wheat systems (Jat et al 2006).
- a district-wise spatial database using socioeconomic indicators to target poverty-prone areas (Erenstein et al 2007c).

These studies aim to help realign the overall RWC research agenda to contribute to achieving the Millennium Development Goals (MDGs) by ensuring environmental sustainability (MDG 7) and by making available adequate supplies of affordable, good-quality food (MDG 1). Time was devoted to document and write up past survey work. Below, the abstracts of the first four studies are reproduced. Most of the underlying reports are available in PDF format on the Web or upon request from the CIMMYT-India office.

Zero-tillage adoption in Pakistan Punjab and Haryana, India (Erenstein et al 2007a): The recent stagnation of productivity growth in the irrigated areas of the Indo-Gangetic Plains of South Asia has led to a quest for resource-conserving technologies that can save water, reduce production costs, and improve production. The synthesis of two detailed country studies confirmed the widespread adoption of zero-tillage (ZT) wheat in the rice-wheat systems of India's Haryana State (34.5% of surveyed households) and Pakistan's Punjab Province (19%). The combination of a significant "yield effect" and "cost-saving effect" makes adoption worthwhile and is the main driver behind the rapid spread and widespread acceptance of ZT in Haryana, India. In Punjab, Pakistan, adoption is driven by the significant ZT-induced cost savings for wheat cultivation. Thus, the prime driver for ZT adoption is not water savings or natural resource conservation but monetary gain at both sites. Water savings are only a potential added benefit.

ZT adoption for wheat has accelerated from insignificant from 2000 onward at both sites. The geographic penetration of ZT is far from uniform, suggesting potential for further diffusion, particularly in Haryana, India. Diffusion seems to have stagnated in the Punjab study area, and further follow-up studies are needed to confirm this. The study also revealed significant dis-adoption of ZT in the survey year: Punjab, Pakistan, 14%, and Haryana, India, 10%. Better understanding of the rationale for dis-adoption merits further scrutiny. Our findings suggest that there is no clear single overarching constraint but that a combination of factors is at play, including technology performance, technology access, seasonal constraints, and, particularly in the case of Punjab, Pakistan, the institutional ZT controversy. In terms of technology performance, the relative ZT yield was particularly influential: dis-adopters of ZT reporting low ZT yields as a major contributor to farmer disillusionment in Punjab, Pakistan, and the lack of a significant yield effect in Haryana, India. At neither site did the ZT-induced time savings in land preparation translate into timelier establishment, contributing to the general lack of a yield increase. Knowledge blockages, resource constraints, and ZT drill cost and availability all contributed to nonadoption. This suggests that there is potential to further enhance access to this technology and thereby its penetration.

The study highlights that, in both Haryana, India, and Punjab, Pakistan, ZT has been primarily adopted by the larger and more productive farmers. The structural differences between the adopters and nonadopters/dis-adopters in terms of resource base, crop management, and performance easily confound the assessment of ZT impact across adoption categories. This calls for a comparison of ZT plots and conventional-tillage plots on adopter farms.

ZT-induced effects primarily apply to the establishment and production costs of the wheat crop. Both the Haryana, India, and Punjab, Pakistan, studies confirmed significant ZT-induced resource-saving effects in farmers' fields in terms of diesel and tractor time for wheat cultivation. Water savings, however, are less pronounced than expected from on-farm trial data. Only Haryana had significant ZT-induced water savings in addition to significant yield enhancement. The higher yield and water savings in Haryana result in significantly higher water productivity indicators for ZT wheat. Both sites have limited implications for overall wheat crop management, the subsequent rice crop, and the rice-wheat system as a whole. The ZT-induced yield enhancement and cost savings provide a much-needed boost to the returns to, and competitiveness of, wheat cultivation in Haryana. In Punjab, ZT is primarily a cost-saving technology. Based on these findings, the study provides several recommendations for research and development in South Asia's rice-wheat system.

ZT impact assessment (Laxmi et al 2007b): To date, the resource-conserving technology that has been most widely adopted in the IGP is zero-till (ZT) wheat after rice, particularly in India. The report reviews and synthesizes the experience with zero-tillage in the Indian IGP. ZT of wheat after rice generates significant benefits at the farm level, in terms of both significant yield gains (6–10%, particularly due to more timely planting of wheat) and cost savings (5–10%, particularly tillage savings). These benefits explain the widespread farmers' interest and the rapidity of diffusion across the Indian IGP, further aided by the wide applicability of this mechanical innovation. The study subsequently reports on the findings of village-level focus-group discussions in Punjab, Haryana, and eastern Uttar Pradesh. These typically corroborate the findings reported in the reviewed literature. They also highlight the significant extent and speed of ZT adoption in each village as well as the substantial cost savings and yield increases. A conservative ex ante assessment of supply-shift gains alone (excluding other social and environmental gains) shows that the investment in ZT/RT research and development by the Rice-Wheat Consortium (RWC) and CIMMYT was highly beneficial, with a benefit-cost ratio of 39, a net present value of $94 million, and an internal rate of return of 57%. The study highlights the potential gains from successful technology transfer and adaptation in natural resource management.

Uptake and impacts of resource-conserving technology options (Singh and Erenstein 2009): The paper assesses the socioeconomics of integrated crop and resource management along a gradient of rice-wheat systems in northern South Asia. Ten clusters of on-farm rice-wheat R&D sites are grouped into three regions: the northwest Indo-Gangetic Plains, the central zone, and the eastern Gangetic Plains. These three regions are contrasted in terms of selected sites, livelihood, and system characteristics and in terms of the adoption and impacts of resource-conserving technologies (RCTs). The paper shows a significant regional variation in rice-wheat systems across northern South Asia, with striking gradients in terms of resources, management practices, and RCT adoption. The R&D activities have had a positive impact on RCT use rates across the project communities. The village surveys also confirm that RCTs generally are cost-saving without a yield loss, thereby enhancing farmers' income. The village surveys do, however, highlight that the better endowed farmers tend to be the first adopters of RCTs. Purposive efforts are therefore needed to ensure that access to and uptake of RCTs are more inclusive. The marked regional variation also emphasizes the need for local adaptation—giving further impetus to the need for on-farm R&D initiatives to help adapt promising technological innovations to the local and diverse circumstances faced by resource-poor farmers.

Adoption and impact of conservation agriculture-based resource-conserving technologies in South Asia (Erenstein, 2009a): The stagnation of productivity growth in South Asia's rice-wheat system has led to increased calls for conservation agriculture–based resource-conserving technologies. To date, the most significant progress has been made in addressing the challenge of reducing tillage. After an initial rapid spread of tractor-drawn zero-tillage drills, particularly in the northwest Indo-Gangetic Plains, the zero-/reduced-tillage wheat area seems to have stabilized there between a fifth and a fourth of the wheat area. Conventional tillage for wheat continues to decline, with an increased use of a rotavator making up the difference, but its intensive shallow tillage goes against conservation agriculture tenets. Zero-tillage wheat allows for a drastic reduction in tillage intensity, with significant costs savings as well as potential wheat yield increases. The cost-saving effect alone makes zero-tillage profitable and is the main driver behind its spread. Zero-tillage impacts so far have been primarily limited to the wheat crop. Moving rice-wheat systems toward conservation agriculture also implies tackling the challenges of reducing tillage for the subsequent rice crop, crop residue retention, and diversification. Equity poses a final challenge and calls for a better understanding of livelihood implications and stakeholder dialogue/participation.

4. FACILITATION AND COORDINATION (ACTIVITY 4)

The RWC facilitated the implementation of numerous participatory research trials at many sites in four countries—India, Bangladesh, Pakistan, and Nepal. This included providing technical backstopping and organizing workshops, training activities, and traveling seminars. The results of some of these activities were published in four major publications: 1) a traveling seminar report titled "Resource-Conserving Technologies for Enhancing Rice Production in the Trans- and Upper Gangetic Plains," (2) Wheat in West Bengal, (3) Production Technology for Direct-Seeded Rice, and (4) Zero-Tillage

Technology for Wheat Sowing. Activities that the RWC carried out related to this project follow:

*i) 15th Regional Technical Coordination Committee (RTCC) and 15th Regional Steering Committee (RSC) meeting***:** The RWC facilitation unit organized its 15th RTCC (biannual) and 15th RSC (annual) meeting on 2-3 February 2009 in New Delhi. A total of more than 130 stakeholders (scientists/extension workers, senior management personnel, policymakers, and representatives of the donor community) participated in this meeting. In this 15th RTCC, a session was devoted to reviewing work done in partnership with various NARES in the USAID project.

ii) National Technical Coordination Committee meetings: The RWC supported the conduct of NTCC meetings in the RWC countries (Bangladesh, Pakistan, and Nepal). These meetings helped NARES partners in reviewing and prioritizing their research program. The following NTCC meetings were held and attended by the RWC coordinator:

- Pakistan: 22 October 2008 in Islamabad
- Bangladesh: 1 November 2008 at BARI, Dhaka
- Nepal: 28 November 2008 at NARC, Kathmandu

iii) Traveling seminars: Traveling seminars are helpful in disseminating new technologies, clearing doubts about the socioeconomic and biophysical impacts of the emerging technologies, and generating new ideas for the refinement and up-scaling of technologies in a farmers' participatory mode. Traveling seminars were organized for key farmers, project staff, student interns, policymakers, and private-sector actors involved in the project to share their information with leading agricultural institutions/organizations and to establish linkage and collaboration with scientists, farmers, agricultural graduates, manufacturers, and other stakeholders involved in other projects in other parts of the same country or in other countries. The seminars provided a unique opportunity to the farmers and officials of eastern India to interact with their counterparts, scientists, machine manufacturers, and service providers of northwest India in understanding the prospects of and constraints to the wider adoption of RCTs. Descriptions of the traveling seminars organized in 2008 are given below:

A) Promotion of RCTs in the eastern and northwestern IGP (25 February to 1 March 2008): The traveling seminar group included farmers from Nepal (7), eastern Uttar Pradesh (10), western Uttar Pradesh (10), West Bengal (3), and Haryana (8); technical officers; scientists and media personnel; and drill manufacturers. The objective of the seminar was to disseminate new interventions related to resource conservation, provide a platform for farmer-to-farmer and farmer-to-scientist interactions, and understand the major constraints to the wider adoption of RCTs. The group traveled more than 1,200 kilometers to see the performance of zero-tillage, raised beds, the Happy Seeder, diversification, and other emerging technologies.

B) Machinery development for rice residue management in the northwest IGP (13 to 20 April 2008): This seminar was conducted in two phases. In the first phase (7 to 12 April), six members of the Indian delegation visited various experimental sites and manufacturers and held discussions with the concerned scientists in Pakistan. The second phase of the traveling seminar took place during 13 to 20 April in India and 8 members of the delegation from Pakistan visited various places in western Uttar Pradesh, Haryana, and Punjab.

C) Promotion of Happy Seeder technology (27-28 April 2008): Thirty scientists from Nepal, West Bengal, eastern Uttar Pradesh, Haryana, and western Uttar Pradesh participated in this traveling seminar to see the performance of ZT wheat sown into crop residues using a Happy Seeder.

D) Resource-conserving technologies for enhancing rice production in the Upper and Trans-Gangetic Plains (7 to 11 September 2008): A total of 31 participants involving farmers, scientists, and technical offficers from the Middle Gangetic Plains (Bihar and eastern Uttar Pradesh) and the Lower Gangetic Plains (West Bengal) took part in the traveling seminar. In addition, media personnel, local farmers, scientists, private seed producers, and machine manufacturers intracted with participants at different sites. The group traveled more than 1,500 km to observe the performance of DSR and different RCT machinery such as a laser-aided land leveler, zero-till machine, raised-bed planter, Happy Seeder, punch planter, inclined zero-till drill, and rotavator.

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