Evaluation and promotion of resource conservation technologies in low land rice-wheat ecosystem

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Abstract

The rice-wheat cropping system is critically important for food security, employment and livelihood of the people in the country. This cropping system is generally practiced in lowland ecosystem where heavier soil texture and excess soil moisture cause serious problems in the establishment of winter crops. Consequently, it increases tillage and land preparation cost and delays planting that resulted into very low yield and income. Conventional tillage and crop establishment methods require more resources, time, labor and energy which are increasingly becoming scarce and expensive. This paper illustrates the results of farmer participatory research on resource conservation technologies (RCTs) implemented in the farmers field of Rupendehi district for two successive years (2006/07 and 2007/08) with the purpose of enhancing adoption of such technologies that would sustain higher and more stable yields with the use of less resources and costs. The results of different RCTs such as zero tillage (ZT), reduced tillage with power tiller seed drill (PTSD) and power tiller rotary (PTR) and surface seeding (SS) revealed great saving in seed, land preparation/ seeding and irrigation costs with significant increment in yield and income indicating their suitability and superiority over conventional tillage (CT) in the given ecosystems.

Key words: Resource conserving technologies, reduced tillage, surface seeding, zero tillage

Introduction

Rice and wheat occupy 1.5 and 0.67 Million ha, respectively and are grown in succession on more than 0.56 Million ha which accounts 37% of the rice and 85% of wheat area in the country (Tripathi *et al.*, 2002). Rice-Wheat System is one of Nepal's principal agricultural production systems and occupies about one fourth of the total cropped area, which provides food, income and employment to over 83% of the Nepalese. Thus, the rice-wheat production system has great importance in assuring food security and enhancing livelihood of the Nepalese populace. Rice- wheat system is largely practiced in rainfed or irrigated low land ecosystem where heavier soil texture, excessive soil moisture, and late harvest of rice lead to higher cost and delays in wheat planting. The traditional method of crop establishment involves excessive tillage and land preparation which is a pain staking, expensive and time-consuming task that further leads to poor plant stand and late planting (Hobbs *et al*. 1997; Tripathi 2002). In this situation, resource conservation technologies (RCTs) such as zero tillage, reduced tillage and surface seeding provide a basket of options to alter crop yield and income of farmers. These technologies provide substantial savings in water, labor and other resources along with early crop establishment, drudgery reduction and environmental protection. It increases cropping intensity and provides options to diversify the r-w cropping system particularly due to early harvesting and time saving. Evaluation and fine-tuning of technology in farmers' field is an integral part of the research and development process before going for large-scale adoption. Participatory approach was adopted to ameliorate economic and environmental factors that may influence the development process and to determine the technical knowledge necessary for fine tuning and adoption of new technologies (Lanyon 1994). Farmers, researchers, and other stakeholders gain a better understanding of the innovation, thereby encouraging its adoption. This approach is more relevant to testing and promoting RCTs because different RCTs requirements vary greatly with the change in locations. With the view of understanding interactions of RCTs and farm mechanization in local environment and enhancing their adoption several activities and experiments were carried out in the farmers' field. However, this paper deals only with evaluation and promotion of different RCTs such as zero tillage, reduced tillage and surface seeding technologies in wheat. Therefore with the view of improving productivity, profitability and sustainability of r-w system, an attempt has been made to evaluate and promote different RCTs in the farming community.

Methodology

Farmer participatory research experiments on different RCTs were conducted in different farmers' field of Rupandehi district for two successive years (2006/07 and 2007/08).

Zero tillage technology

Evaluation of zero tillage wheat against conventional tillage

Zero tillage (ZT) wheat was tested against farmer's conventional tillage practice (CT) with three elite wheat varieties: Gautam (V1), Bhrikuti (V2), and BL1473 (V3). Each of the wheat variety replicated in 20 farmer fields and experimental data were analyzed in on-farm participatory module with factorial RCBD using one farmer field as one replication across the locations. Gen stat 3.2 statistical packages were used in analyzing experimental data for all the field experiments reported in this document. All of the field experiments were conducted in low land fields that would have remained fallow in winter season because of excess soil moisture at planting time. Experimental sites were having higher clay percentage and poor drainage (internal and external) system which are typical characteristics of the low land fields in the area.

Effect of planting time and varieties on zero tillage against conventional tillage wheat

After the review of first year experimental results it was realized that wheat planting goes more than a month starting from around 15 November and majority farmers plant their wheat little later than the appropriate time. Therefore, in the second year, all stakeholders agreed and suggested to conduct another experiment including two planting dates. Since it was not possible to select one or two dates due to nature of the experiment, we selected a range of planting time: November (normal or timely planting) and December (Late planting). Planting time was added as one more factor with two levels keeping all the 3 varieties and 2 planting methods as used in previous study. Each of the wheat variety replicated in 4 farmer fields with two levels of planting methods and one level of planting time which involved a total of 48 farmers. For the analysis purpose 6 farmer field data of 12 treatments (3 varieties x 2 tillage methods x 2 planting time) were considered as one replication. Experimental data were analyzed in on-farm participatory module with factorial RCBD design using one farmer field as one replication across the locations.

Reduced tillage

Two reduced tillage (RT) methods such as power tiller seed drill (PTSD) and power tiller rotary (PTRT) were tested along with farmers practice (FP) using 2 popular wheat varieties (Gautam and Bhrikuti). The same approach and methodologies were used as described for zero tillage wheat. One reduce tillage method with both the varieties was kept in one farmers field and each method replicated in 4 farmers field. Thus 3 farmer field data using 3 different methods with 2 varieties (3 x 2) made one set of replication for the purpose of statistical analysis. Altogether 24 farmers were involved in the testing of reduced tillage technology in both of the years (2006/007 and 2007/008). All the experiment plots of participating farmers were of low land rice fields fall under similar domain.

Surface seeding

Surface seeding (SS) technology was tested and demonstrated against farmer's conventional practice (FP) in 30 farmer fields using 3 wheat varieties (BL1887, Bhrikuti and Achyut). One variety was kept in one farmer field under both SS and CT replicated in 10 farmer fields. In this technology, wheat seeding was done either prior to rice harvest or just after rice harvest based on feasibility and environmental conditions. In most of the farmer fields the farmer conventional tillage practice (CT) could not followed because of excess soil moisture, which did not allow any tillage operations to plant wheat with conventional tillage. Therefore, in most cases this technology was demonstrative type as there was nothing to compare with except fallow lands. However 3 sets of data were managed to compare with conventional tillage at each sites, thus total of six farmers participated in this experiment. Other farmer fields were used only for demonstration of SS wheat against fallow fields.

Initial impact assessment

An initial impact assessment was done at the end of second year to collect some information that how farmers have adopted and what their opinion toward RCTs in general was. Therefore, a quick survey was attempted asking few questions to the farmers. Altogether 138 households were contacted for the purpose. They were simply asked to compare before and after situation as they remember.

Results

Zero tillage technology

The data of the first experiment: evaluation of zero tillage wheat and variety interaction showed great impact of zero tillage method over conventional tillage consistently in both the years (Table1). The overall variety differences were also observed as Gautam produced higher grain yield than the two varieties (Bhrikuti and Bl1473) but differences were not pronounced (Table1).

Table.1 Effects of different planting methods and varieties on wheat grain yield (kg/ha) over two years

	Planting methods effect:		
Method	**Year1**	**Year2**	**Combined (2Yrs)**
Zero tillage	2763	2911	2837
Conventional tillage	1813	2271	2042
F test	<.001	<.001	<.001
LSD value	96.5	122.9	86.9
CV%	11.6	13.1	14
Variety effects:			
Gautam	2363	2882	2623
Bhrikuti	2234	2519	2376
BL1473	2266	2372	2319
F test	0.083	<.001	<.001
LSD value	118.2	150.5	106.4
CV%	11.6	13.1	14

The interaction between planting methods and varieties were not consistent as in the first year all 3 varieties produced significantly higher grain yield under zero tillage with no statistical differences among them either in zero tillage or in conventional tillage. Whereas in the second year, Gautam produced significantly higher yield than Bhrikuti and BL1473 under both the tillage practices. However, Bhrikuti also produced significantly higher grain yield than BL1473 under conventional tillage. The combined analysis also showed similar significant interaction as it was observed in year two (Fig.1).

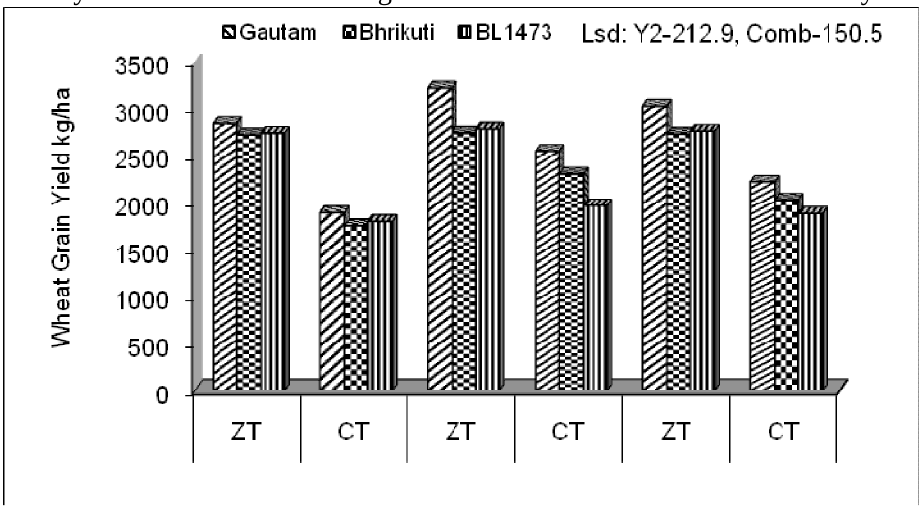

Fig. 1 Interaction between wheat varieties and planting methods

In the next experiment where planting time was also included as a factor with planting method and varieties showed great interaction between variety and planting time and between planting method and planting time (Fig.2), however, no interaction was observed between planting method and varieties which indicates that all 3varieties have similar yield potential and change in planting method does not have much impact on variety performance. There was strong interaction between variety and planting time, for instance Gautam variety performed better in normal planting but showed poor performance in late planting under both the tillage practices and sites while other two varieties showed reasonably good response to late planting (Fig. 2).

Zero tillage performed equally better in normal and late planting with marked differences in grain yield over conventional tillage (Fig. 2). The conventional tillage found to have low yield potential in either case.

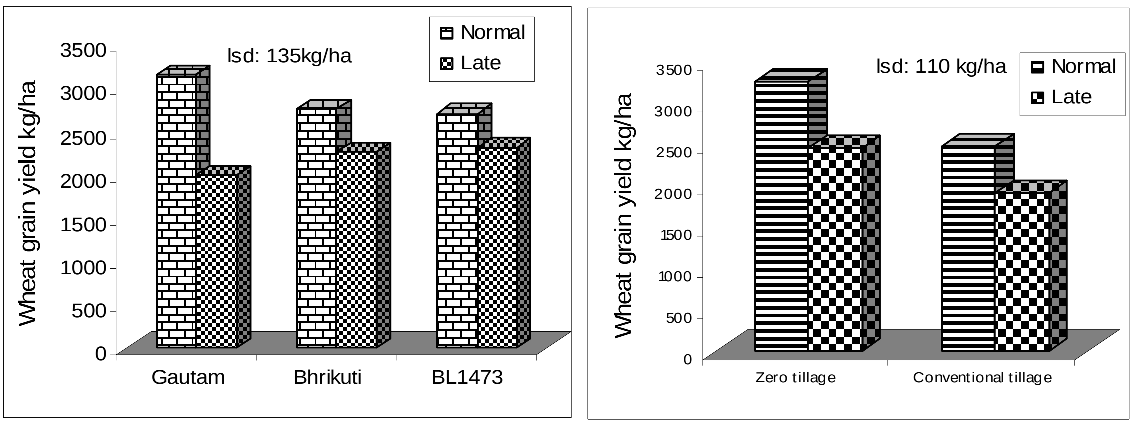

Fig. 2 Showing Interaction effects between variety and planting time (Left) and planting method and planting time (right) on wheat grain yield (kg/ha)

The economic analysis of zero tillage wheat revealed great saving in seed, land preparation/ seeding and irrigation costs as saved by 20%, 63% and 40% respectively over conventional tillage (Annex.1). Zero tillage reduced the total cost of cultivation by 20% and also increased the total income by 33% as an accumulation of cost saving and yield increment. Net benefit increased by more than 1.5 folds (155%) and a higher benefit cost ratio of 1.36 indicates significant economic return from a new technology against 0.43 from conventional tillage (Annex.2).

Besides the participatory experimentation more than 100 farmers of both the sites also adopted zero tillage on their own input with the provided equipment and consultation from the project and farmer groups. Farmers from neighboring villages of the project sites also followed zero tillage by hiring equipments from the groups. All together 295 farmers adopted zero till wheat covering 174 ha area at the sites and in surroundings. Most of the farmers did zero tillage wheat in the low land fields where wheat crop was not grown previously due to excessive soil moisture. The success of zero tillage technology in fallow fields has brought tremendous contentment and enthusiasm among farmers. Thus, farmers have not only increased their wheat area as compared to previous years but also increased productivity and profitability from wheat crop at both the sites which ultimately contributed to enhance food security and livelihood of the small and medium farmers of Rupandehi district.

Reduced tillage (RT)

Two methods of reduced tillage (RT) technology: power tiller seed drill (PTSD) and power tiller rotary (PTR) were tested against conventional tillage (CT) practice along with two popular varieties for two consecutive years 2006/007 and 2007/008 in wheat. Statistical analysis of grain yield data showed that all 3 methods of wheat planting performed differently as they produced significantly different amount of grain yield. Both reduced tillage methods: PTSD and PTR proved superior to that of CT however, performance of both the RT methods also differed greatly with each other proving PTSD the best practice among all (Fig.3). Two popular varieties were used also differ with each other consistently as Gautam out yielded for both the years over Bhrikuti. Similar level and pattern of significance observed for both the years for different planting methods as well as varieties. Interaction were not significant except year x variety x PM (planting method) because the performance of both varieties in PM varied year to year.

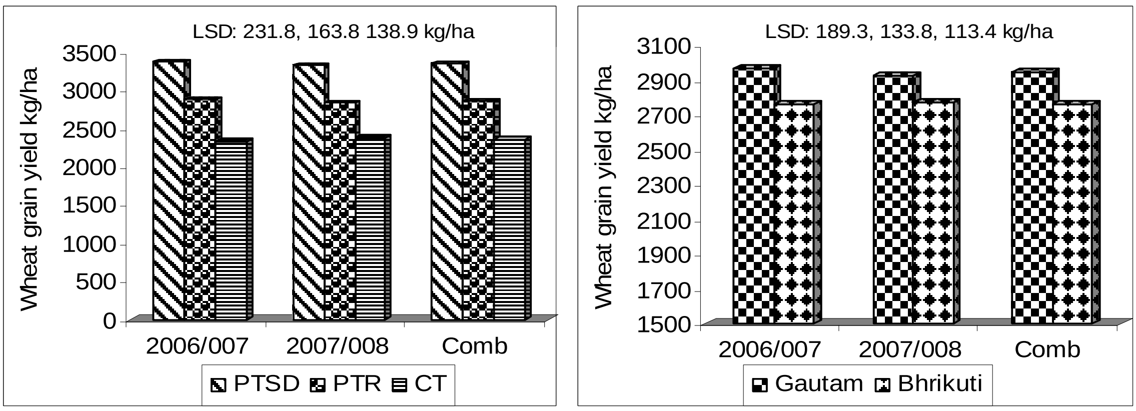

Fig. 3 Performance of different planting methods (Left) and variety performance over the years

Economic analysis showed that out of 2 reduced tillage methods PTSD saved 20% seed cost, 56% land preparation cost and 30% irrigation cost against conventional tillage whereas PTR saved only of irrigation cost by 20% (Annex.1). There was no saving in seed and land preparation cost in PTR because of rotary tilling and manual broadcasting of seeds like in conventional methods therefore similar expenses were observed to that of CT. Of the total cultivation cost, PTSD saved 18% where as PTR saved only 2% against conventional tillage (Annex.2). The reduced tillage method with PTSD offered very handsome economic return as indicated by 223% higher net benefit over CT with 1.68 benefit cost ratio. This economics is more stunning than any of the RCTs due to great savings in input costs and higher yield advantages. However, PTR provided 114% higher net benefit with 0.93 benefit cost ratio which is lesser than ZT and PTSD but still much higher than conventional tillage (Annex.2).

Surface seeding in wheat

Surface Seeding technology was tested in 6 farmer fields for 2 consecutive years in rice–fallow low land fields. Surface seeding wheat was evaluated with conventional tillage in such fields where either linseed/lentil crops are grown for very marginal yields or kept fallow due to excessive soil moisture at the time of wheat planting. The grain yield data showed higher yield benefit with SS technology in both the years (Table 2). Year wise data also showed significant yield increase in year 2, may be 1st year experiences of the farmers lead to better management of wheat in such problem fields. Over all surface seeding produced 2684 (kg/ha) grain yield of wheat against 1982 kg/ha which is more than 35% higher over conventional tillage with almost no land preparation and planting costs. In the demonstration plots where SS technology was demonstrated to occupy low land fields with wheat, showed similar results to that of experimental fields (Table 2). The mean wheat grain yield of demo plots from different farmers' field revealed that surface seeding provided a very reasonable yield and handsome return against fallow fields with all tested varieties (Table 3).

Table 2. Grain yield (kg/ha) of Surface seeded wheat against conventional tillage

Year	SS	CT
2006/007	2394	1641
2007/008	2974	2323
Mean	2684	1982
Statistical analysis	YR	PM
F test	<.001	<.001
LSD	225.2	225.2
CV%	11	

Table 3. Grain yield (kg/ha) of surface seeded wheat against fallow (demonstration plots)

VAR	Year1	Year2	Mean
Gautam	2362	2512	2437
Bhrikuti	2694	2882	2788
Achyut	2542	2735	2638
Mean	2533	2710	2621

Like in zero tillage and reduced tillage, SS method of wheat planting also offered great savings in input costs over conventional tillage. Surface seeding technology helped in saving of 33% seed cost, 97% land preparation and seeding cost and 60% of irrigation cost. The savings obtained due to SS technology are even more pronounced than other RCTs such as zero tillage and reduced tillage (Annex.1). Data obtained from economic analysis of SS wheat revealed 29% saving in total cost of cultivation and 26% increment in total (gross) income against conventional tillage. The saving in cost of cultivation and handsome gross return lead to achieve 152% higher net benefit and 1.52 benefit cost ratio from SS technology in wheat (Annex.2). In most cases, this technology was adopted where no crops were grown due to excess soil moisture and difficulty in operating tillage equipments, therefore whatever has been achieved from this technology is 100% gain over fallow land.

Initial impact

Initial impact study showed very good impact as 87% farmers adopted either zero tillage (56%) or reduced tillage with PT (31%). Only 13% farmers did not adopt any RCTs because of either inaccessibility to the RCT equipments or less interest (Fig.5). The adoption of zero tillage is quite higher than the power tiller and further increased in the 2nd year tremendously. The adoption of RCTs leads to tremendous increase in number of wheat growers (26%), wheat area (195%) and productivity (109%) as compared to previous situation which succeeded to bring >90% of fallow land under wheat cultivation at the research sites (Table 4). Farmers were asked to evaluate different RCTs as they feel and observed during two years of project period. Eighty three percent farmers rated zero tillage technology either very good (51%) or good (32%) and 1% found not so good whereas 16% could not express their opinion as they have not yet used this technology. Similarly for power tiller technology 52 % farmers reported the use of PTs and they rated either very good (33%) or good (19%) whereas 48% farmers said that they have not used yet but it seems good technology and they will certainly use if machines are accessible to them.
During interaction with the farmers it was learned that reduction in land preparation and planting costs, timely planting and higher yields have attracted farmers toward zero tillage in a big way. Small farmers observed great savings in hours of use for that they pay the renting cost of tillage equipments while big

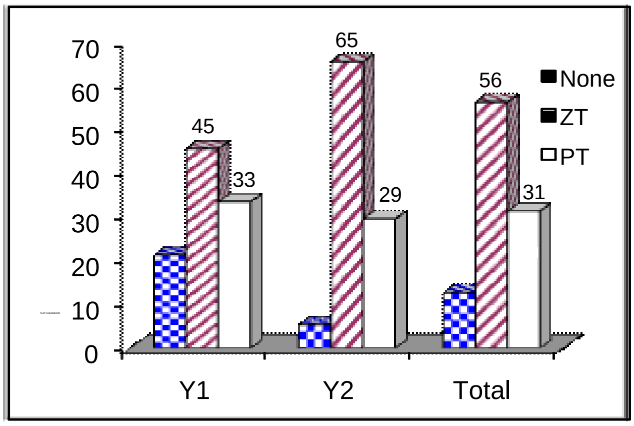

Fig. 4 Adoption zero tillage and power tillage by % of farmer respondents

farmers who usually own tractor calculated great diesel savings at their own farm. We found many farmers of giving such examples of saving costs and making benefits from different RCTs in one or other way depending on farmers own resources and circumstances during interaction at many events. The amount of benefit varies location to location and farmer to farmer depending on resources, circumstances and type of technology adopted.

Table 4. Percent change in number of growers, area and production of wheat due to introduction of RCTS

Particular	No. of grower	Area (ha)	yield (kg/ha)	Fallow land (ha)
Before	105	31.9	1079	72.2
After	132	94.2	2251	7.1
% change	25.7	195	108.6	-90

Discussion

All tested RCTs like zero tillage, reduced tillage with power tiller and surface seeding technologies provided great reduction in the cost of cultivation, higher yield and benefit over farmers' conventional tillage at both the research sites. Similar results were reported by many authors in Nepal and South Asia (Gupta 2003; Hoobs, 2003, 2001; Tripathi *et al*., 2002; Sah, 2002; Gupta *et al.*, 2002). Farmers found these RCTs very suitable to establish wheat crop in lower wet land fields where heavier soil texture with excess soil moisture compelled them to leave their lands fallow after rice. Varietal differences in zero tillage were not pronounced as all 3 varieties performed equally better, however some interaction were observed with the influence of location (site) and years. This is some what different than what was reported earlier (Tripathi *et al;* 2005) because the use of best and similar type of varieties in the experiments might have affected the significance level. The planting time has the greatest effect on the performance of varieties and planting methods indicated by interaction between planting time and variety and between planting time and methods (Tripathi *et al;* 2005; Giri 1996, 1998). Zero tillage provide measures to avoid late planting as it advances the planting by 15-21 days in our condition and it has been advocated by many authors with some variation in days (Gupta *et al.* 2002; Hobbs 2001; Hobbs *et al.*1997). It has been also clearly observed that if late planting is unavoidable, zero tillage with appropriate variety could also provide the best option. Reduced tillage either with PTSD or with PTR proved better than CT that gives shallow tilling and prepares fine seed bed in only one pass with PTSD and or two passes with PTR (Sah, 2002). These RT methods are not only economic but also increase the yield due to best use of top soil for crop establishment. The interaction between planting methods and varieties was not significant indicating that there was no influence of any factor over each others performance. But year wise interaction between planting method and variety differ greatly showing that the variety performance in different planting methods has been influenced by year as climatic and weather conditions vary year to year. Surface seeding is a technology to adapt when RCT equipments can not be run due to excess soil moisture and or late rice harvest which either delays wheat planting or compel farmers to keep their land fallow. In such cases this technology could help farmer to plant wheat either in standing rice crop before harvesting (relay) or after harvest in vacant field (Hobbs, 2003; Tripathi *et al.* 2002, 2000; Giri 1998). Farmers' experienced better performance of surface seeded wheat than the conventional tillage. Moreover it helps farmers occupy their wasted land (fallow) with wheat cultivation that provide 100% gain where no tillage equipment can be used due to excess soil moisture. This technology provides 35-100% gains depending on situations.

All these RCTs (ZT, PTSD, PTR and SS) provide better yield performance and greater economic benefit in low land fields. The yield advantages in all these RCTs are the cumulative effects of change in management practices according to land type, soil texture and hydrology. These changes essentially advances planting time, seed and fertilizer placement at optimum depth, greater seed soil contact and fine seed bed preparation (power tiller), all of which attributed to increased input use efficiency and better crop growth converting in to yield. Moreover, the negative effect of excess soil moisture or water logging at root zone greatly reduced and optimum plant growth of (root and shallow) is obtained. These RCTs also offers substantial savings in tillage and land preparation cost, irrigation costs and seed costs. Precise planting in a single pass with these equipments greatly reduced the crop establishment and seed costs and less absorption of water in no till or shallow tilling situation decreases the irrigation cost for ZT and PT. However in SS, usually pre-germinated seeds are used therefore a little less seeds are required than the recommended seed rate and as seeds are broadcasted by hands in no till situation, it eliminates the land preparation cost and provides 100% saving in crop establishment. Saving in cultivation costs with little higher or similar yield benefits provides handsome return and that is the reason that why these technologies more viable and acceptable to the farmers. Assessing initial impact at both the research sites and in surroundings great adoption of different RCTs has been observed within the two years of participatory research and development. Zero tillage has been largely adopted by the farmers, however there was less craze about PT particularly due to low capacity and less availability of machine. The tremendous increase in area, productivity and economic benefits has definitely helped in improving livelihood of the farmers. The assessed impacts are only indicative of experimental sites; however impacts are even greater in surrounding villages.

There is always some deficiencies and limitations associated with the use of new technologies. Major limitations of these technologies are: recognizing appropriate soil moisture for planting and proper drilling of the seeds without any lapses (Tripathi *et al.*, 2006) that needs little knowledge about the machinery that how it works and practical experiences which can be gained by training or experiencing in the field during adoption. Moreover, the availability of zero tillage seed drill and power tiller seed drills locally are the major issues for large scale adoption.

Conclusion

It is obvious that different RCTs like ZT, RT and SS technologies are best suited to the low land ecosystem. They have ability to reduce the cost of cultivation on one hand and increased the yield on the other hand. Therefore, these technologies are not only technically feasible and of problem solving type but also economically viable to persuade farmers for large scale adoption. The participatory method of testing technologies ensures the direct involvement of farmers with the sense of doing research for themselves, which lead to ownership and self pride. Zero tillage with 4 wheel tractors and reduced tillage with power tiller could be used in all areas over terai. However SS technology is more suitable to the problem fields where no equipment can be used for tillage and crop establishment because of excess soil moisture. It is apparent that farmers are able to reduce the cost of cultivation, increase crop yield and best utilize their resources to the possible extent through the adoption of RCTs and farm mechanization strategies. In addition, diesel consumptions for tillage and land preparation and irrigation is reduced from which not only millions of dollars can be saved every year but also there would be less carbon emission to the environment.

The adoption of these technologies has been spreading in the district rapidly as farmers have learned that which technology is beneficial for which type of land and conditions. They have learned that how farm mechanization can help them and moreover they are much more aware of these technologies than in the past. Now, an attempt has also been made to put these technologies into national agricultural extension network at higher level and also incorporated at district level planning. However, most of the RCTs are machinery based therefore availability of these machineries and spare parts at local level would be the key for large scale adoption. Therefore, manufacturers, importers and traders must be encouraged to ensure the availability of equipments.

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Annex 1. Cost of Cultivation for wheat production using RCTs and conventional tillage as different planting methods

Input/ output	Particulars in details	CT	ZT	PTSD	PTR	SS
Wheat Seed	Amount kg/ha	150	120	120	150	100
	Cost NRP/ha	5250	4200 (20%)	4200 (20%)	5250	3500 (33%)
DAP kg/ha	Amount kg/ha	108	108	108	108	108
	Cost NRP/ha	3780	3780	3780	3780	3780
Urea	Amount kg/ha	173	173	173	173	173
	Cost NRP/ha	3460	3460	3460	3460	3460
MOP	Amount kg/ha	45	45	45	45	45
	Cost NRP/ha	900	900	900	900	900
Land preparation & seeding	No. of tillage and planking	4	1	1	2	0
	No. of hours by tractor	8	3	6	16	0
	Cost NRP/ha	4800	1800 (62.5%)	2100 (56.3%)	4800	100 (97.9%)
Irrigation	No. of irrigation	1	1	1	1	1
	Time taken from STW h/ha	10	6	7	8	4
	Cost NRP/ha	2250	1350 (40%)	1575 (30%)	1800 (20%)	900 (60%)
Weed control	Herbicide +1labor cost NRP/ha	0	500	0	0	500
Harvesting & carrying	No. of Labors/ha	35	35	35	35	35
	Cost NRP/ha	3500	3500	3500	3500	3500
Threshing	Tractor thresher h/ha	3	3	3	3	3
	Cost NRP/ha	1050	1050	1050	1050	1050
Cleaning & Storing	No. of Labors/ha	3	3	3	3	3
	Cost NRP/ha	300	300	300	300	300
Total costs	NRP/ha	25290	20340	20865	24750	17990
Wheat production	Grain yield kg/ha	2128*	2837	3346	2861	2684
	Straw yield kg/ha	4149*	5228	4585	4356	4750
Income NRP/ha	Grain @ Rs16	34048	45392	53536	45776	42944
	Straw	2075	2614	2293	2178	2375
Total Income NRP/ha	Wheat + Straw	36123	48006	55829	47954	45319
Net Income NRP/ha	Income + Cost in hectare basis	**10833**	**27666**	**34964**	**23204**	**27329**

Note: Figures given in the parenthesis are indicating the % saving over CT and signed with * are average yields calculated from different experiments for economic analysis purpose.

Annex 2. Economic analysis in terms of cost saving, net income and benefit cost ratio from different Resource Conserving Technologies in wheat

Planting methods	Total Cost NPR/ha	Saving in cost NPR/ha	Gross Income NPR/ha	Net Benefit NPR/ha	% Net Benefit increased	Benefit Cost Ratio
CT	25290	-	36123	10833	-	0.43
ZT	20340	4950(19.6%)	48006	27666	155.4	1.36
PTSD	20865	4425 (17.5%)	55829	34964	222.8	1.68
PTR	24750	540 (2.1%)	47954	23204	114.2	0.93
SS	17990	7300 (28.9%)	45319	27329	152.3	1.52