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EVALUATION OF RESOURCE CONSERVATION TECHNOLOGIES IN RICE-WHEAT SYSTEM OF PAKISTAN

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SUMMARY

Resource conservation technologies (RCTs) like laser land levelling, rice transplanter, wheat sowing with zero tillage and by bed and furrow methods were evaluated in the rice-wheat zones of Punjab during 1999-2000. The impact assessment of RCTs was mainly based on the comparison of the farms adopting RCTs *vs* the farms practising conventional methods.

- In rice fields, after harvesting, sufficient moisture is available. If the soil is ploughed as it is conventionally practised, it not only wastes the moisture reserves in the soil but also causes extra financial and physical burden on farmers in term of ploughing, planking and pre-sowing water applications (*rouni*). Moreover, it unnecessarily delays the wheat sowing for couple of weeks that finally affects the crop yield. However, these fields could be sown at proper time using zero tillage with the minimum resources available.

- Land preparation and sowing cost/acre of zero tillage farms was significantly less than conventional farms. On zero tillage farms, the cost ranged from Rs.164 to 179/acre, while on conventional farm, it ranged from Rs. 863 to 900/acre.

- Seed rate used on RCTs farms was slightly lower as compared to non-RCTs farms. Moreover, the efficiency of fertilizer use was greater on RCTs farms as compared to conventional farms. On zero tillage, laser levelling, bed & furrow and conventional farms, average fertilizer use efficiency was 24, 23, 24 and 20, respectively.

- Weed density with bed & furrow was the minimum followed by zero tillage and laser levelling. On conventional farms, plant density was the highest. Plant density on RCTs wheat farms ranged from 75 to 131 plants/m^2 against 104 plants/m^2 on non-RCTs farms.

- Soil salinity increased slightly with zero tillage because of low water application after harvesting of high delta rice crop. However, this salinity was not seriously affected by wheat sowing methods and remained within safe limits. Moreover, zero tillage gave better results in improving the soil fertility due to decomposition of rice stubbles. The infiltration rate of soil by using zero tillage technique was also 43 percent greater than traditional sowing method.

- Average yield/acre for wheat crop in case of laser levelling was the highest with 1856 kg/acre followed by zero tillage with 1812 kg, bed & furrow with 1673 kg and conventional farms with 1615 kg/acre.

- In mechanical rice transplanting, 96 percent less man-hours were required as compared to manual or conventional transplanting. Two acres of rice can be transplanted by mechanical transplanter as compared to one acre by manual transplanting during the same time. Reduction in sowing time and labour was the main benefit of mechanical transplanting. Yield per acre on mechanical rice farms was 1305 kg whereas it was 1297 kg/acre on manually transplanted fields.

CHAPTER 1

INTRODUCTION

1.1 Background

Pakistan is an agricultural country. The agricultural sector contributes 26 percent to the Gross Domestic Products (GDP), provides 80 percent of total national export and employs 54 percent of the labour force. At present, population of the country is increasing at a rate of 2.68 percent annually. To meet the need of ever increasing population, crop production will have to increase accordingly. This increase in agriculture productivity can be achieved either by bringing more area under cultivation or by increasing the per acre crop yield. The desire to bring more area under cultivation is limited with the availability of land, which is being used for industrial and urban development. Other constraint for bringing more land under cultivation is the availability of water resources. However, the yield per acre could be increased by adopting resource conservation technologies like laser land levelling, zero-tillage and furrow-bed method of surface irrigation.

1.1.1 *Water Productivity*

Water is one of the most important environmental factors and inputs for crop production. It is a scarce source in arid and semi-arid areas. The importance of efficient use of this precious crop input increases as the world population increases. Qutub and Nasiruddin (1994) reported that the Pakistan Rabi shortfall of 3.5 million acre foot (MAF) could increase to 13 MAF by the year 2017. At this stage, country would need more food and fiber to meet the needs of the growing population. This shortfall has to be met either by constructing new reservoirs or by improving the water use efficiency at the farm. The construction of new reservoirs have financial and environmental constraints. Whereas the efficiency of the irrigation system could be improved easily by adopting proper technologies (Ashraf *et al*., 1999a). Therefore, there is a need to achieve maximum production per unit of water applied.

1.1.2 *Land Productivity*

Land is the most important natural resource since it provides the basis for crop and livestock production. However, this resource is heavily affected by erosion, deforestation, overgrazing, urbanisation, industrialisation, waterlogging and salinity. The sustainable agriculture production could only be achieved by the proper management and use of land resources, which includes the soil conservation and maintenance of its productivity.

Pakistan covers an area of 80 million hectares (mha) of mainly arid or semi-arid land, of which about 31 mha (39 percent) is suitable for agriculture and forestry. Approximately 20 mha are cultivated (16.2 mha are being irrigated), 3 mha are exploitable forest, and 8 mha are rangeland. Nearly, 61 percent are under cash crops, and the remaining 23 percent are shared by other crops such as oilseeds, fruits, fodder etc (Saeed, 1994).

Soils of Pakistan are generally low in organic matter and its nutrients are being depleted due to increase in cropping intensity, improper crop rotation, waterlogging, salinity and also due to natural and man induced erosion. To achieve the goal of self-sufficiency in food and fibre, and to alleviate the poverty from the country, this precious resource should be used judiciously and in a sustainable way. Appropriate activities must be carried out to reduce the soil erosion and to conserve soil nutrients to enhance the agricultural productivity of the soils.

1.1.3 *Crop Productivity*

Wheat is a staple food in Pakistan. In the coming years, the wheat requirement of the 150 million population will be 21.42 million tons. However, the wheat produced in the country is far below than the requirement (except in 1999-2000) due to which the country has to import wheat to feed its people. Only in 1998, Pakistan imported 4.11 million tons of wheat (MINFAL, 1998). During the next ten to twelve years, the wheat requirement will be 25 to 30 million tons. Such a huge demand could only be achieved by increasing the yield per acre.

In Pakistan, wheat is grown on an area of 8.1 mha. Out of which Punjab contributes 5.8 mha i.e. 72 percent of the total area. In Punjab, 34 percent of the total culturable land area is devoted to wheat. It is estimated that rice-wheat zone of Punjab covers an area of 1.1 mha stretched in the districts of Sialkot, Gujranwala, Sheikhupura, Narowal, Hafizabad, Lahore, Kasur and Gujrat. In these districts, 72 percent of the wheat is grown in rotation with rice. But wheat yield is low as compared with those of other cropping systems in Punjab (Chaudhry *et al*., 1999).

Rice is second major food crop and is cultivated almost in all provinces in Pakistan. Pakistan grows rice on about 2.24 mha, of which 60 percent area lies in Punjab followed by Sindh with 30 percent, and remaining 10 percent area lies in NWFP and Balochistan. Average yield of rice in Pakistan is far below than the potential yield as compared to other countries having similar agro-climatic conditions (Kahlown *et al*., 2000). Moreover, the average wheat yield in Pakistan is 1851 kg ha^{-1}, whereas it is 3102 kg ha^{-1} and 4077 kg ha^{-1} (almost double) in China and Mexico, respectively (Kahlown *et al*., 1999).

The main reasons for the low yield are the unnecessary delay in wheat sowing due to high cost of sowing or the non-availability of labour. In rice fields, after harvesting, sufficient moisture is available. If the soil is ploughed as it is conventionally practised, it not only wastes the moisture reserves in the soil but also causes extra financial and physical burden on farmers in term of ploughing, planking and water applications *(Rouni)*. Moreover, it unnecessary delays the wheat sowing for couple of weeks that finally affects the crop yield. Wheat yield decreases at a rate of 1 percent every day delay in sowing after mid of November (Aslam *et al*., 1999). Moreover, due to the labour and energy problems, some farmers leave their lands fallow. Nevertheless, these fields could be sown at proper time using resources conservation technology (zero tillage) with the minimum resources available.

1.1.4 *Agricultural Machinery*

Mechanization in agriculture played an important role in green revolution. However, it has some adverse impacts on environment. According to Census of Agricultural Machinery 1994, about 0.25 million tractors of different makes are being used in Pakistan (MINFAL, 1998). Irrational use of agricultural machinery can compact soil unduly and disturb soil horizons. The soil compaction also reduces the porosity in the soil and results in poor aeration. It reduces the soil infiltration, intake rate and internal percolation of water. It also helps develop a hard pan in soil, which creates temporary waterlogging and retards the penetration of roots, which consequently affects the crop yield. The damaging effects of soil compaction can be quite considerable.

1.2 Resource Conservation Technologies

1.2.1 *Mechanical Transplanting*

In Pakistan, rice is an important food and cash crop. It meets the total rice requirements of the country and a substantial fraction of fine rice is exported to earn foreign exchange.

Past efforts like on farm water management, high yielding rice varieties, mechanized farming and improved extension services have increased the yields in the Indus plains. However, all these efforts have not been able to bridge the gap in rice productivity between Pakistan and other countries. One of the basic reasons for low yields is the low plant density and improper row-to-row and plant-to-plant distance. Plant density on farmer's fields is often observed from 40000 to 50000 plants per acre as compared to 75000 to 80000 recommended by experts (Kahlown *et al.*, 1999).

To overcome the scarcity of labour and ensure recommended plant density, Farm Machinery Institute (FMI) has modified a Chinese rice transplanter, which suits best to local farming conditions. This is available in two models *i.e.* RT-12 (12 rows) and RT-8 (8 rows). These models are capable of transplanting 3 and 5 acres of rice in a day respectively. This machine is an economical substitute of traditional manual rice transplanting. Rice yield can be increased by about 20 percent by ensuring proper crop stand establishment through use of mechanical transplanter (Ashraf *et al*., 1999b).

1.2.2 *Laser Land Levelling*

Pakistan's agriculture is classified as an irrigated having about 17 mha of irrigated area and 90 percent of its agriculture production comes from irrigated lands (Mohtadullah, 1997). Nearly 50 percent of the total available irrigation water is lost in transit in tertiary level irrigation system, and at the farm during application to crops (Gill, 1994). A significant amount of irrigation water is wasted due to undulated fields and due to field ditches. Johnson *et al*. (1977) reported that precision land levelling increased the crop yield per acre from 725 to 984 kg. Moreover, the mean time to irrigate an acre field was reduced from 2.12 hrs to 1.13 hrs.

Precision land levelling (PLL) is a topographic modification, grading and smoothing of land to an even level, with little or no slope with an elevation difference of $\pm$ 2 cm. Precision land levelling improves irrigation application efficiency and increases the uniformity of water application with less chance of over and under irrigation. Therefore, the problems related to over and under irrigation are eliminated. It has been reported that PLL increased the land use intensity from 8-63 percent and cropping intensity from 6-70 percent (Gill, 1994). Therefore, levelled field helps reduce the amount of irrigation water required and helps reduce the labour requirements. On Farm Water Management (OFWM) has recently procured laser-guided PLL technology for attaining higher accuracy in levelling work and land levelling work in almost all tehsils of Punjab is in progress. This research was undertaken to study the impact of laser land levelling on water savings and crop production.

1.2.3 *Zero-Tillage Technology*

In zero tillage or direct planting, seed is placed directly in the uncultivated soil through the mulch layer with the help of a seed drill. Several kinds of seed drills have been developed for the purpose. Weed control has been the major concern in the use of zero-tillage technology. However, green manuring, mulching and suitable crop rotation help keep the weeds minimum. Direct planting increases the soil fertility especially the organic matter in the soil, infiltration and moisture retention. Moreover, zero or minimum tillage helps reduce the CO_2 emission. It has been estimated that zero tillage technique could reduces world's CO_2 emissions by as much as 16 percent (Steiner *et al*., 1998). Zero tillage saves time, labour, cost of cultivation besides conserving and stabilising the soil. It eliminates the destruction of soil structure and allows build up of soil microbial activities. Because of less tractor wheel traffic, surface soil compaction is reduced. Positive effects also come from the elimination of continual mixing of weed seeds with soil, which takes place with tillage.

Because of higher surface organic matter and moisture, slightly lower soil temperatures have been reported with direct drilling. This method also improves internal soil drainage. Average costs of operation, repair and maintenance of machinery are reduced with long-term use of this technique (Choudhry, 1990).

In contrast, ploughing and turning the soil reduces the organic matter in the soil. Tillage and hoeing are extremely labour and energy intensive. Therefore, the availability of labour and machinery are the deciding factor in the adoption of zero tillage technology.

In America 17.3 mha are grown with zero tillage whereas in Brazil 5 mha are sown with this technique. This technique was first developed in Brazil in early 1970s to check massive soil erosion. Moreover, 3 mha of land is sown with zero tillage in Argentina. In Africa, zero tillage is applied mainly in South Africa and Zimbabwe and to a lesser extent in Kenya and Tanzania (Steiner *et al*., 1998). Zero tillage technology was introduced in Pakistan during 1997 by the OFWM, Punjab and more than 11,000 acres have been sown by this technique in Punjab during 1999-2000 *rabi* season (OFWM, 1999).

1.2.4 *Bed and Furrow Irrigation*

Surface irrigation is the most ancient method of irrigation and has been practiced on about 90 percent of the irrigated area of the world (Keller, 1992). However, application efficiency of surface irrigation is still below the available levels. Berkhout (1997) attributed the low application efficiency of surface irrigation to infiltration characteristics of soil, field undulations, intake discharge and run-off.

Surface irrigation techniques can be improved by developing crop specific field layouts. Efficient surface irrigation methods such as bed and furrow irrigation system helps to save water. Kahlown *et al*., (1998) compared the results of cotton and wheat sowing on flat basin and on bed and furrow. They concluded that cotton yield maximum water use efficiency for bed and furrow method of irrigation whereas the flat basin method of irrigation, the most commonly used method in Pakistan, had the lowest yield and the highest water consumption. Therefore, the water saved in bed and furrow irrigation can be used to increase the cropping intensity and also for leaching the salts in salt affected soils. Based on the water use efficiency, the bed and furrow method is the most efficient surface water application method.

In bed and furrow method, water is applied only in furrows. With the passage of time, the furrows become cemented due to silt deposition. Water then moves laterally and vertical seepage of the water reduces considerably. Since water is applied in furrows, the effect of water born and water transmitted diseases on the crop health is minimal. The weeds, which are transported through canal water, are trapped in the furrows from which these can be removed or controlled easily. Moreover, the same field may be used for inter-cropping *e.g.* sugarcane in furrows and wheat on beds *etc*. Extra cost involved in land preparation of bed and furrow field is Rs.100 per acre, which when compared to the total cost involved is only 3 percent (Alberts and Kalwij, 1999).

1.3 Rationale for Investigation

On Farm Water Management (OFWM) Punjab has introduced laser land levelling, zero tillage and bed & furrow technologies. Since these technologies are new, therefore it was essential that the impact of these RCTs be evaluated before their adaptation on large scale in the country. Therefore, the Mona Reclamation Experimental Project (MREP) Bhalwal and On-farm Water Management, Punjab undertook this study jointly.

1.4 Objectives

This study was undertaken to evaluate the impact of resource conservation technologies on the water and crop production and to compare these with the conventional methods. The specific objectives were:

- To evaluate the impact of resource conservation technologies on water saving, soil health, sowing time, tillage cost, crop inputs, fertilizer use efficiency, weed control and crop yields.
- To conduct the economic analysis of resource conservation technologies.

1.5 Study Area Location

This study was conducted in irrigated area of the Punjab. Zero tillage and laser levelling trials were conducted in the districts of Gujranwala, Sheikhupura, Okara, Pakpattan, Kahnewal and Sahiwal. In addition to these technologies, two more improved technologies like bed and furrow and mechanical rice transplanting were also tested in the Mona Project Area, Bhalwal, Chak 44/SB, Sargodha, Mureedkay, Sheikhupura and Mallomechay, Sialkot.

CHAPTER 2

METHODOLOGY

Resource Conservation Technologies (RCTs) concern with conserving water resources, minimizing cost of crop production and increasing per acre crop yield. These technologies allow the farmer to pick and choose profitable alternative of agriculture rather than practicing conventional agriculture with less return. The RCTs include laser land levelling, zero tillage, bed & furrow and mechanical transplanting. The former three improved technologies were used on wheat farms located at Chak 44-SB village, Mona village, Mureed Kay village and Melomehay village while the fourth was used on rice farms at Phularwan and Chak 7 NB of Mona village.

A field survey was conducted in 1999-2000 to evaluate the impact of RCTs on increase in yield and net benefits of rice (1999) and wheat (1999-2000). Both the rice and wheat farms under improved technologies were compared to conventional farms of respective crop to assess the impact of RCTs. For field data collection, a field pre-tested questionnaire was used. Mona and OFWM, Punjab conducted this survey. For rice field, the parameters like cultural practices, seed rate, use of fertilizers, number of irrigations, labour charges for harvesting and threshing were constant both for transplanter planting and manual transplanting. The main difference was observed in terms of time spent for sowing (*i.e.*, reduction in labour hours), plant densities and yields.

The second field survey was conducted by OFWM, staff for wheat crop 1999-2000. The RCTs used on wheat farms were zero tillage and laser levelling. These technologies were used in various districts of Punjab including Sheikhupura, Gujranwala, Okara, Pakpattan, Sahiwal and Khanewal.

The first survey encompassed most of the information pertaining to experimental research data. This survey covered four improved technologies. Out of these three (zero tillage, laser levelling and bed & furrow) were used for wheat cultivation and the remaining one (mechanical transplanting) for rice cultivation. In the second field survey, information was recorded by the field staff. This survey covered only two technologies (zero tillage and laser levelling). Difference in survey data and mode of data collection provided a base for separate analysis of the survey data resulting from each survey. Part-I of the following chapter deals with the analysis based on data from 1st survey. The Part-II relates to analysis based on data from the 2nd survey.

2.1 Indicators Monitored

In order to collect information/data on various aspects of water conservation, sowing time, fertilizer use efficiency, weed control, crop inputs and yields, the following indicators were used for the evaluation of RCTs:

2.1.1 *Sample Size*

In the first survey as the size of sample population was small, so the entire population of 34 farmers was interviewed with 6 farmers from Chak 44 SB, 13 from Mona village, 10 from Malomehay and 5 from Mureedkay area.

In total, 71 wheat farms were surveyed from 32 farmers, with 39 farms where improved technology was used and 32 farms where wheat was sown by conventional methods. Thirty nine improved farms included 24 farms where wheat was sown with zero tillage, 10 farms which were precisely levelled with laser before wheat sowing and 5 farms where wheat was planted with bed & furrow method. However, on 32 conventional farms wheat was sown without adopting any improved sowing method (Table 1). Four rice farms were surveyed from 2 farmers. Mechanical and manual (conventional) methods of rice transplanting were compared at two farms.

Table 1: *Sample Population and Use of Various Technologies on Rice and Wheat Farms*

Location	*No. of farmers interviewed*		*Number of Farms under Different Technologies*							
			Rice		*Wheat*			*Total*		
	Rice	*Wheat*	*Mech.*	*Manual*	*Zero Tillage*	*Laser Levelling*	*Bed & Furrow*	*Conv.*	*Rice*	*Wheat*
Chak 7 NB	2	11	2	2	10	2	2	13	4	27
Chak 44 SB	-	6	-	-	-	6	1	5	-	12
Mureedkay	-	5	-	-	5	-	2	5	-	12
Malomehay	-	10	-	-	9	2	-	9	-	20
Total	*2*	*32*	*2*	*2*	*24*	*10*	*5*	*32*	*4*	*71*

In the 2nd survey, size of sample population under laser levelling was too small. So, the entire population of 7 farmers was surveyed. However, in case of zero tillage, a reasonable size of sample population was available. In order to draw more consolidated results, the whole population of 103 farmers was included in the survey (Table 2).

In total, 220 farms were surveyed from 110 farmers with 103 farms where wheat was sown with zero tillage and 7 farms which were precisely levelled before sowing of wheat crop. There were 110 wheat farms where wheat was sown by conventional method (Table 2).

2.1.2 *Development of Questionnaire*

A comprehensive questionnaire was developed (Annexure-I). It was pre-tested in the field and as a result, necessary amendments were made to improve its workability. Keeping in view the objectives of the study, the following parameters were studied:

- Characteristics of the farm area;
- Area covered by each technology;
- Irrigation frequency;
- Soil salinity and fertility;
- Infiltration rate;
- Water quality;
- Use of farm inputs; and
- Crop yields.

Table 2*: Sample Population and Use of Various Technologies on Wheat Farms*

Location	*No. of Farmers*	*No. of Farms under Different Technologies*			*Total*
		Zero Tillage	*Laser Levelling*	*Conventional*	
Distt. Gujranwala	**13**	**13**	**-**	**13**	**26**
(i) Gujranwala	2	2	-	2	4
(ii) Noshera Virkan	3	3	-	3	6
(iii) Hafizabad	2	2	-	2	4
(iv) Wazirabad	4	4	-	4	8
(v) Kamonkee	2	2	-	2	4
Distt. Sheikhupura	**70**	**70**	**-**	**70**	**140**
(i) Sheikhupura	55	55	-	43	98
(ii) Nankana Sahib	4	4	-	4	8
(iii) Ferozwala	11	11	-	11	22
Distt. Okara	**12**	**12**	**-**	**12**	**24**
(i) Depalpur	12	12	-	12	24
Distt. Pakpattan	**10**	**8**	**2**	**10**	**20**
(i) Pakpattan	3	2	1	3	6
(ii) Arifwala	7	6	1	7	14
Distt. Khanewal	**3**	**-**	**3**	**3**	**6**
(i) Khanewal	2	-	2	2	4
(ii) Mian Channu	1	-	1	1	2
Distt. Sahiwal	**2**	**-**	**2**	**2**	**4**
Total	*110*	*103*	*7*	*110*	*220*

2.1.3 *Area Covered by RCTs on Sample Farms*

The distribution of farm area covered by each of the four improved technologies and conventional farms is shown in Table-3. In Chak 44 SB, total farm area under improved technology was 113.25 acres under wheat crop. Out of 113.25 acres, 83.5 acres were precisely levelled with laser before sowing of wheat crop and on 2.5 acres; wheat was planted with bed and furrow method making 74 and 2 percent of total wheat area, respectively. On the remaining 27.25 acres, wheat was planted with conventional methods. This was 24 percent of wheat area.

In Malomehay village, total area under sampled farms was 260.5, 149.5 acres were under zero tillage and 12 acres were laser levelled making 57 and 5 percent of total wheat area respectively. Thirty eight percent (99 acres) farms were sown with conventional method.

In Mureedkay village, total area under sampled wheat farms was 168 acres. Out of these 54 acres were under zero tillage and only 2 acres were under Bed and Furrow making 32 and 1 percent of total wheat area respectively. On sixty seven percent farms conventional methods were used for wheat sowing.

In Mona village, total area of sampled wheat farm was 87.50 acres, with 26 acres where wheat was grown with Zero Tillage, 7 acres which were levelled with laser levelling before sowing of wheat. These constituted 30 and 8 percent of total wheat area, respectively. On sixty two percent farms (54.5 acres), wheat was planted with conventional methods. The 3 acres of rice were planted by mechanical method making 5 percent of the total rice area on sample farms. On 95 percent farms (55 acres), rice was planted by manual or conventional method (Table 3).

Table 3: *Distribution of Farms Area by Type of Technology*

Technology	*Chak 44/SB*		*Malomehay*		*Mureedkay*		*Mona Village*			
	Wheat Farms						*Rice Farms*		*Wheat Farms*	
	Average	*%*	*Average*	*%*	*Average*	*%*	*Average*	*%*	*Average*	*%*
Mechanical Transplanting	-	-	-	-	-	-	3	5	-	-
Zero Tillage	-	-	149.5	57	54	32	-	-	26.0	30
Laser Levelling	83.5	74	12.0	7	-	-	-	-	7.0	8.0
Bed & Furrow	2.5	2	-	-	2	1	-	-	-	-
Conventional	27.25	24	99.0	38	112	67	55	95	54.5	62
Total	*113.25*	*100*	*260.5*	*100*	*168*	*100*	*58*	*100*	*87.5*	*100*

Distribution of farm area covered by improved technologies and conventional farms, which were surveyed by OFWM, is shown in Table 4. In Gujranwala, Sheikhupura and Okara districts, only zero tillage was used for wheat cultivation on sample farms. Area under this technology was 56, 75 and 50 percent respectively of total wheat area of the respective districts. In district Pakpattan, both the zero tillage and laser levelling were practiced. Area under these technologies was 52 percent of total wheat area with 40 percent (21.5 acres) under Zero Tillage and 12 percent (6 acres) under Laser Levelling. In districts Khanewal and Sahiwal Laser Levelling was used on 33 and 50 percent of total area under wheat farms (Table 4).

2.1.4 *Data Analysis*

To analyze the impact of RCTs on rice and wheat productivity, the primary data collected from both the field survey were used. The data covered information mainly on land preparation and farm inputs-outputs. The data were expressed in monetary terms using farm gate and market prices applicable for both inputs and outputs. Economic analysis was also done to estimate benefits based on crop yield and water saved from RCTs on sample farms.

Table 4: *Distribution of Farms Area by Type of Technology (Based on OFWM Data)*

Location	*Zero Tillage*		*Laser Levelling*		*Conventional*		*Area under Technology*	*Percent of Total*
	Average	*%*	*Average*	*%*	*Average*	*%*		
Distt. Gujranwala	**280**	**56**	**-**	**-**	**218**	**44**	**280**	**56**
(i) Gujranwala	5	1	-	-	2	1	5	1
(ii) Noshera Virkan	100	20	-	-	63	12	100	20
(iii) Hafizabad	24	5	-	-	108	22	24	5
(iv) Wazirabad	65	13	-	-	15	3	65	13
(v) Kamonkee	86	17	-	-	30	6	86	17
Distt. Sheikhupura	**2676.5**	**75**	**-**	**-**	**889.0**	**25**	**2676.5**	**75**
(i) Sheikhupura	2425.0	68	-	-	735.5	21	242.5	68
(ii) Nankana Sahib	118.5	3	-	-	108.5	3	118.5	3
(iii) Ferozwala	133.0	4	-	-	45.0	1	133.0	4
Distt. Okara	**40**	**50**	**-**	**-**	**40**	**50**	**40**	**50**
(i) Depalpur	40	50	-	-	40	50	40	50
Distt. Pakpattan	**21.5**	**40**	**6**	**12**	**26.5**	**49**	**27.5**	**52**
(i) Pakpattan	4.5	8	3	6	6.5	12	7.5	14
(ii) Arifwala	17.0	32	3	6	20.0	37	20.0	38
Distt. Khanewal	**-**	**-**	**7.5**	**50**	**7.5**	**50**	**7.5**	**50**
(i) Khanewal	-	-	5.0	33	5.0	33	5.0	33
(ii) Mian Channu	-	-	2.5	17	2.5	17	2.5	17
Distt. Sahiwal	**-**	**-**	**3.0**	**50**	**3**	**50**	**3**	**50**
Total	*3018.0*	*71*	*16.5*	*1*	*1184*	*28*	*3034.5*	*72*

CHAPTER 3

RESULTS AND DISCUSSION

The main objective of the study was to evaluate the impact of RCTs on water and land productivity. The parameters studied were land preparation and sowing cost, cultural practices, sowing dates and use of seed rate, irrigation, use of fertilizer, weed infestation, soil health, plant and weed densities and crop yields. Analysis of these parameters based on data from Ist survey is described in Part-I while the analysis of data from the 2nd survey is discussed in Part-II.

PART-I

3.1.1 Land Preparation and Sowing Cost

Land preparation includes cultural practices like land levelling, ploughing, planking and preparation of land at the time of sowing. On the farms surveyed, soil preparation for crop sowing was mostly done by tractor. Cultivation with bullocks was rarely done. Cultivator was the most popular and frequently used implement for tillage. Some progressive farmers had disc harrows, rotavators and soil turning ploughs as well. Number of ploughing and planking practiced on sample farms is shown in Table 5. On wheat farms on average, 10 ploughings and 5 plankings were done both on improved and conventional farms.

Table 5: *Number of Ploughing and Planking on Wheat Farms*

(per acre)

Technology	*Ploughing*	*Planking*
Zero Tillage	-	1
Laser Levelling	4	2
Bed and Furrow	4	2
Conventional	6	3

Zero tillage is the most cost effective method for wheat sowing. In this method wheat is planted with a special drill without any land preparation after harvesting of rice crop. This technique not only saves turn around time by about 10 to 15 days but also reduces the cultivation cost to a considerable extent. The Table 6 shows that cultivation cost with zero tillage was only Rs.164/acre.

Laser Levelling or Precision Land Levelling (PLL) allows for uniform distribution of fertilizers and irrigation water. It was revealed through field survey that on a farm of 25 acre, PLL increased cultivated area from 0.75 to 1 acre. Laser Levelling cost Rs.900 per acre.

Bed and furrow is a water saving method. In this method crop is planted on beds of various widths. Plants on these beds get moisture through water flowing in the furrows. Land preparation and sowing cost incurred on this method was Rs. 850 per acre.

Conventional method concerns with old and unimproved farm practices. This method yields less net returns than advance methods. Land preparation and sowing cost under this method amounted to Rs.863 per acre, which was almost equal to the cost incurred on bed & furrow. It was much higher as compared to zero tillage and slightly higher than bed planting.

Sowing cost of rice is shown in Table 7. Cost of sowing by mechanical method was much higher than conventional method. The main difference in cost was due to high rent of machine. However, time and labour hours spent by mechanical method were much less compared to conventional method of rice transplanting. The most important benefits of mechanical transplanting perceived by the farmers were in terms of higher plant density per acre and reduction in labour hours required for sowing of rice.

Table 6*: Land Preparation and Sowing Cost of Wheat*

(Rs./acre)

Technology	*Levelling*	*Ploughing*	*Planking*	*Sowing*	*Total*
Zero Tillage	-	-	50	114	164
Laser Levelling	190	500	100	110	900*
Bed & Furrow	-	500	100	250	850
Conventional	-	616	182	65	863

*Annualized cost calculated assuming 15 percent interest rate and a life period of 5 years.

Table 7*: Sowing Cost of Rice 1999*

(Rs./acre)

Technology	*Nursery*	*Transplanting charges*	*Total*
Mechanical	200	1000	1200
Manual	100	400	500

Data presented in Table 8 indicate that 96 percent less man-hours were required in mechanical transplanting as compared to conventional transplanting. In case of mechanical transplanting, only four men were required for 3 to 3.25 hours per acre to operate transplanter whereas 5 to 6 men were needed for 4 to 5 hours per acre for manual tranplanting. This indicates that two acres of rice can be transplanted by mechanical transplanter as compared to one acre by manual transplanting. Reduction in sowing of time and labour was the main benefit of mechanical transplanting.

Table 8*: Time and Labour Saved on Rice Farms in Mona Village*

Technology	*Phularwan Farm*			*Mona Village*			*Average*
	Men	*Hrs.*	*Men hrs.*	*Men*	*Hrs.*	*Men hrs.*	*Men hrs*
Mechanical	4	3	12	4	3.25	13.0	12.50
Manual	5	5	25	6	4	24	24.50

3.1.2 Sowing Period

The optimum time of planting wheat in the rice areas of Punjab is from 1-15 November. Farmers continue planting up to the end of December but yields are drastically reduced. Wheat cultivation in such areas, if done with zero tillage saves time by 15 days and reduces the cultivation cost to a considerable extent. No pre-soaking irrigation (*rauni*) is required in case wheat is planted in rice harvested fields as the crop is sown in residual moisture (*wad wattar*). Data regarding sowing dates is given in Table-9. This table shows that as the period of sowing increased, seed rate used for wheat per acre also increased.

3.1.3 Seed Rate

Use of improved seed was much encouraging in the area. Some farmers used seed retained from the previous crop, while the other used seed obtained from Government Seed Corporation and private companies. Seed rate used by the farmers varied from 52 to 54 kg per acre on RCTs farms and on conventional farms seed rate used was 55 kg per acre. On improved and unimproved farms, there was no significant different in the use of seed rate. Recommended seed rate should be 45-50 kg per acre for wheat (OFWM, 1999). Seed rate used on both RCTs and non-RCTs farms looked somewhat on higher side. Wheat varieties mostly planted in the study area included Inqilab 91, Punjab-96 and MH-97. Use of seed rate both on RCTs farms and non-RCTs farms is shown in Table 9. Rice seed rate used both for mechanical and conventional rice farms was 10 kg per acre. The variety Super Basmati was sown on both the farms.

Table 9: *Sowing Dates and Seed Rate for Wheat 1999-2000*

(kg/acre)

Sowing Time	*Zero Tillage*	*Laser Levelling*	*Bed & Furrow*	*Conventional*
4th week of Oct. to 1st week of Nov.	50	52	50	52
2nd week of Nov. to 3rd week of Nov.	52	54	51	54
4th week of Nov. to 1st week of Dec.	53	55	53	55
2nd week of Dec. to 3rd week of Dec.	55	57	54	59
Average	52	54	52	55

3.1.4 Method of Planting

Wheat was planted by rabi drill, pora and broadcasting methods. Rabi drill was the most popular method of sowing, particularly on improved wheat farms. Almost all the wheat planting on zero tillage farms was done with zero tillage drill. Pora, for wheat, being a laborious and time consuming alternative, was the least adopted practice on improved farms. Broadcasting was the least exercised practice. However, on conventional farms, a reasonable area was covered by this method. Rice was planted by mechanical transplanter on improved farms and by manual or conventional method on conventional farms.

3.1.5 Irrigation

Sources of irrigation in the study area were canal and private tubewells. The quality of irrigation water is shown in Table 10 both for wheat and rice farms. There were only two rice fields in Mona village. The one was located at the farm of Asif Bashir and the other at Phularwan Farm. Asif Bashir planted both rice and wheat by improved methods. So, the quality of irrigation water was the same for both the crops. Conjunctive use of irrigation water was the common practice because canal supplies in the area are inadequate. On wheat farms of zero tillage, 3 to 4 number of irrigations were applied as compared to 5 irrigations on non-RCTs wheat farms. Measured data on irrigation depth for wheat crop were available regarding zero tillage and conventional farms in Mona village. The discharge was measured with a cut-throat flume. Analysis of this data is shown in Table 11. On an average 0.33 acre ft (AF) of water per acre was saved on sample farms under zero tillage technology. Based on prevailing water rate of Rs.900 per acre foot charged by private tubewell owners, value of water saved, arrives at Rs.297/acre.

Table 10: *Quality of Irrigation Water Used for Wheat and Rice Farms in Mona Village*

Farmer	*TDS (ppm)*	*pH*	*SAR*	*RSC (meq/l)*	*Source*
Fazal Ahmed	960	8.5	0.39	-	Tubewell
M. Aslam	960	7.5	8.9	0.7	Tubewell
M. Hayat	173	7.5	1.23	-	T/well + Canal
Faiz Ahmed	185	7.5	1.63	-	”
Shaukat Amin	179	7.5	1.67	-	”
Asif Bashir	541	7.5	5.5	0.3	Tubewell
Rice Farms					
Phularwan Farm	224	7.4	1.5	-	T/well + Canal

Table 11: *Depth of Irrigation and Water Saved on Sample Farms of Wheat in Mona Village*

Farmer	*Discharge (Q) (cusecs)*	*Zero Tillage*			*Conventional*			*Water saved (AF)*
		No. of Irrigation	*Time taken (hrs-mnt)*	*Depth of Irrigation (inches)*	*No. of Irrigation**	*Time taken (hrs-mnt)*	*Depth of Irrigation (inches)*	
Fazal Ahmed	1.30	4	1-55	9.88	4	2-15	11.60	0.14
M. Aslam	1.30	4	1-45	9.02	4	2-0	10.31	0.11
M. Hayat	1.5	4	1-55	11.40	5	2-50	21.07	0.80
Faiz Ahmed	1.40	4	1-45	8.79	4	2-30	13.88	0.42
Shaukat Amin	1.3	3	2-5	7.74	3	3-0	11.60	0.32
Asif Bashir	1.5	4	1-50	10.91	4	2-50	16.86	0.50
Average	1.38	4	1-53	9.62	4	2-34	14.22	0.33

* Excludes pre-sowing Irigation.

3.1.6 Fertilizer

Farmers mostly relied on commercial fertilizers to rejuvenate their exhausted soils. Farmyard manure (FYM) was also a source of fertility, but to a limited extent. Green manuring was very rare. So, analysis of FYM and green manuring was not done. Use of nitrogenous fertilizers was much more than the phosphate and potash fertilizers. Phosphate and potash fertilizers were applied invariably as basal, while nitrogen was applied generally in two to three split doses *i.e.*, with 1st, 2nd and 3rd irrigation. Fertilizer application was mostly by broadcasting. The major handicaps, pointed out by the farmers, were low purchasing power against extremely high fertilizer prices, lack of credit facilities, uncertain supply, fertilizer adulteration and below standard weights. In case of zero tillage, the farmer applied NPK 13 kg less compared to conventional method. The reason of this difference was stated to be the placing of fertilizer close to seed in zero tillage. This difference was 9 kg and 12 kg with laser levelling and bed and furrow, respectively compared to conventional farms respectively (Table 12).

3.1.7 Weed Infestation

Weeds and crop plants grow under the same environment and have the same requirement for growth and development. Both extravert moisture and soil nutrients from the same soil, take CO_2 and light for photosynthesis from the same atmosphere and accommodate their build up within the same spacer. As both live in the same biosphere, competition takes place for a particular factor when it falls short of the demand of both.

Weeds densities before and after application of weedicides and their per acre cost are given in Table 13. Weed density with bed and furrow was the minimum followed by zero tillage and laser levelling. The weed was the highest on conventional farms. The similar trend in cost was observed in case of bed and furrow and zero tillage. The cost was maximum with laser levelling (Table 13). Weed density both on improved and conventional rice farms was negligible.

Table 12: *Average Fertilizer Application for Wheat under Different Technologies*

(kg/acre)

Technology	*N*	*P_2O_5*	*K_2O*	*Total NPK*
Zero Tillage	41.8	25.0	1.0	67.8
Laser Levelling	43.1	28.7	-	71.8
Bed and Furrow	45.6	23.0	-	68.6
Conventional	51.9	28.9	-	80.8

Table 13: *Weed Infestation and Use of Weedicide*

Techniques	*Weed Density (m^2)*		*Weedicide cost (Rs./acre)*
	Before weedicide	*After weedicide*	
Zero Tillage	67	10	332
Laser Levelling	89	11	480
Bed and Furrow	63	9	310
Conventional	96	13	406

3.1.8 Soil Health

3.1.8.1 Soil Salinity and Fertility Analysis

Six sample farms were selected in the vicinity of Chak 7 NB, Distt. Sargodha. Soil samples were collected from five different specific points and a composite sample was prepared for salinity and fertility appraisal of each depth *i.e.*, 0-15 and 15-30 cm soil depth.

a) *Soil Salinity*

Data presented in Table 14 indicate that there was a slight increase in all the salinity components in each cropping technique except ECe in conventional method which was decreased in upper layer 5.2 to lower layer 36.4 percent. Increase in salinity was due to low water application after harvesting of high delta rice crop. By cultivation and mixing up the soil in conventional method, salts were removed to the lower layer. Over all soil salinity was not seriously affected by sowing wheat with both the techniques and remained with safe limits.

Table 14: *Soil Salinity as Affected by Sowing Wheat (1999-2000)*

Salinity Components	*Depth (cm)*	*Zero Tillage*			*Conventional*		
		Pre-sowing	*After harvesting*	*Percent decrease/ increase*	*Pre-sowing*	*After harvesting*	*Percent decrease/ increase*
pH	0-15	7.6	7.9	+ 3.9	7.6	7.8	+ 2.6
	15-30	7.6	8.3	+ 9.2	7.6	8.0	+ 5.2
EC_e	0-15	1.7	2.5	+ 47.0	1.9	1.8	- 5.2
	15-30	1.6	1.9	+ 18.7	2.2	1.4	- 36.4
SAR	0-15	5.5	8.7	58.2	5.2	5.7	+ 9.6
	15-30	5.5	8.2	49.0	6.4	7.1	+ 10.9

b) Soil Fertility

Soil fertility was significantly increased in both the techniques except phosphorous (Table 15). It was due to inadequate use of phosphatic fertilizers. After harvesting of rice crop, stubbles were earlier decomposed in zero tillage technique and added adequate organic matter in both depths by 43.6, 66.7 percent as compared to conventional method 21.0 and 36.0 percent. Nitrogen was added about 10 percent more in upper soil layer and 21 percent more in 15-30 cm soil layer. Potassium was also 9 percent more in upper soil layer. Therefore, zero tillage can best use the fertilizer applied.

3.1.8.2 Infiltration Rate on Sample Farms

Infiltration rate of soil was measured by double ring infiltrometer before and after harvesting of wheat crop in samples farms at Chak 7 NB. The infiltration rate of soil increased in each farm by each farming technique (Table 16). It was significantly increased, upto 106 percent, in zero tillage and 63 percent by conventional sowing method. The infiltration rate of soil by using zero tillage technique is 43 percent more than traditional sowing method. This indicates that zero tillage is more supporting technology which keeps the soil loose and porous and plants roots get adequate CO_2 whereas conventional sowing method causes compaction and plant roots cannot get water easily.

Table 15*: Soil Fertility as Affected by Sowing of Wheat in Mona Village*

Fertility Components	*Depth (cm)*	*Zero Tillage*			*Conventional*		
		Pre-sowing	*After harvesting*	*Percent decrease/ increase*	*Pre-sowing*	*After harvesting*	*Percent decrease/ increase*
O. M. (%)	0-15	0.87	1.25	+ 43.6	0.95	1.15	+ 21.0
	15-30	0.42	0.70	+ 66.7	0.50	0.68	+ 36.0
N (%)	0-15	0.048	0.063	+ 31.2	0.048	0.058	+ 20.8
	15-30	0.024	0.037	+ 54.1	0.027	0.036	+ 33.3
P (ppm)	0-15	7.0	5.2	- 25.7	6.7	5.5	- 17.9
	15-30	5.0	3.2	- 36.0	5.2	3.8	- 26.9

K (ppm)	0-15	140	172	+ 22.8	147	167	+ 13.6
	15-30	125	170	+ 36.0	120	164	+ 36.0

Table 16*: Infiltration Rate of Soil as Affected by Sowing of Wheat 1999-2000*

(cm/hr)

Farmer	*Zero Tillage*		*Conventional*	
	Pre-sowing	*After Harvesting*	*Pre-sowing*	*After Harvesting*
Fazal Ahmed	0.4	1.0	0.5	0.9
M. Aslam	0.5	0.8	0.4	0.9
M. Hayat	0.6	1.3	0.6	1.3
Faiz Ahmed	0.5	0.8	0.5	0.8
Shaukat Amin	0.3	1.2	0.4	1.1
Asif Bashir	0.6	1.1	1.1	0.9
Average	*0.5*	*1.03*	*0.6*	*0.98*
Percent increase		*106*		*63*

3.1.9 Plant Density

Plant densities of all planting techniques are presented in Table 17. Maximum plants and tiller per acre were found in zero tillage technology and in levelled soils whereas minimum plants and tiller per acre were found in conventional method of wheat sowing. Maximum plants 400/m^2 were in zero tillage due to the availability of suitable soil moisture and fertilizer in ionic form to the embryo of seeds for radical germination. In laser-levelled fields, plant gets available moisture but its radical found food in his surrounding due to which tillering occurs. On an average basis 1139 tiller/m^2 were found in zero tillage more than conventional, bed and furrow planting and zero tillage 932, 900 and 1131, respectively.

Table 17: *Plant Densities under Different Sowing Techniques for Wheat*

Farming Techniques	*Maximum*		*Minimum*		*Average*	
	Plants/m^2	*Tillers/m^2*	*Plants/m^2*	*Tillers/m^2*	*Plants/m^2*	*Tillers/m^2*
Zero Tillage	400	1020	124	756	262	1131
Laser Levelling	375	1125	130	780	253	1139
Bed and Furrow	308	924	91	546	200	900
Conventional	356	676	110	671	233	932

Bed and Furrow planting showed less plants than conventional due to the space left for ditches. This was covered by smooth and equal germination of plant in the fields and good tillering which gave 900 tiller/m^2 with little difference to the conventional technique. The healthy plants due to better uptake of soil nutrients covered the difference of fallow space with only 72 kg less yield than conventional.

Data regarding plant densities of Rice 1999 transplanted both by mechanical and conventional method is shown in Table 18. The table shows that there was a slight variation in plant densities resulting from both the methods. However, plant density can be increased in mechanical method, if gapping or plant missing could be avoided. This can be done by improvement/modification in transplanter design.

Table 18: *Plant Densities for Rice 1999*

Farming Techniques	*Maximum*		*Minimum*		*Average*	
	Plants/m²	*Tillers/m²*	*Plants/m²*	*Tillers/m²*	*Plants/m²*	*Tillers/m²*
Mechanical	24	480	18	180	21	305
Manual	21	525	13	143	17	306

3.1.10 Crop Yield

Factors like soil fertility, soil preparation and management, application of fertilizers, quality of seeds, timely sowing of crops, quality of seed, pesticides and adoption of better cultural practices all affect crop yields. Only a close inter-relationship between all these input items guarantees high crop yields. RCTs allow mainly for proper management of soil, efficient use of water resource and in time crop sowing. All the three input factors play an important role in shifting the production function upward. To evaluate the impact of RCTs on wheat yields, yield data was analyzed separately for each technology. A maximum yield of 1928 kg/acre was obtained on Laser Levelled farms. This followed by zero tillage with 1871 kg/acre and conventional with 1745 kg/acre. On bed & furrow farms the yield obtained was lowest *i.e.* 1673 kg/acre (Table 19).

Table 19: *Yield Statistics of Wheat on Sample Farms*

(kg/acre)

Technology	*Yield*	*Percent Increase Over Conventional*
Zero Tillage	1871	7.22
Laser Levelling	1928	10.49
Bed and Furrow	1673	- 4.13
Conventional	1745	-

To evaluate the impact of planting methods for rice 1999, yield data was analyzed separately for mechanical and conventional method, which is shown in Table 20. The table shows that yield obtained from mechanical method was slightly higher than conventional method. On rice field at Chak 7 NB, where gaps were left by transplanter machine were filled with new plants, the yield was 4.05% higher compared to conventional method. At Phularwan Farm gap were not filled, therefore, resulted in decrease in yield on mechanical farm by about 4 percent as compared to conventional farm.

Table 20: *Yield Statistics of Rice on Sample Farms in Mona Village*

(kg/acre)

Location	*Methods of Rice Transplanting*	
	Mechanical	*Manual*
Chak 7 NB	1540	1480
Phularwan Farm	1071	1115
Average	*1305*	*1297*

Effect of sowing time on wheat yield both for zero tillage and conventional farms is shown in Table 21. Yield of wheat sown on the same dates was higher on zero tillage farms as compared to conventional farms. As time of sowing increased, yield decreased. Late sowing of wheat by about 2 weeks reduced yield by 71 kg/acre. In the third and fourth sowing period, it further decreased by 411 and 693 kg/acre, respectively. On conventional farms, yield decreased by 99, 326 and 592 kg/acre in the 2nd, 3rd and 4th sowing respectively compared to 1st sowing, which lasted to the end of 1st week of November.

3.1.11 Water Use Efficiency (WUE)

Water use efficiency is a simple estimate to measure how accurately irrigation water has been used for crop production. Any effort which tends to increase crop yield or reduce the amount of water needed without disturbance to crop yield will increase the water use efficiency. In this investigation, water use efficiency has been worked out as kg of wheat grains per cubic metre of water applied.

Data given in Table 22 indicate that water use efficiency obtained on RCTs farms was much higher as compared to non-RCTs or conventional farms. Water use efficiency obtained with bed & furrow was the highest followed by laser levelling, zero tillage and conventional farms. Water saved on laser levelling, zero tillage and bed & furrow was 0.25, 0.22 and 0.435 acre-ft with a value of Rs.225, 198 and 392 per acre.

Table 21: *Effect of Sowing Time on Wheat Yield*

(kg/acre)

Sowing Period	*No. of Cases*	*Zero Tillage*	*Marginal Decrease*	*Conventional*	*Marginal Decrease*
4th week of Oct. to 1st week of Nov.	2	2231	-	2094	-
2nd week of Nov. to 3rd week of Nov.	6	2160	71	1995	99
4th week of Nov. to 1st week of Dec.	8	1820	411	1768	326
2nd week of Dec. to 3rd week of Dec.	6	1538	693	1502	592

Table 22*: Water Use Efficiency of Wheat on Sample Farms in Mona Village*

Description	*Units*	*RCTs Farms*			*Non-RCTs Farms*
		Laser Levelling	*Zero Tillage*	*Bed & Furrow*	*Conventional*
Water Applied	m^3/acre	1153	1187	923	1461
	acre-ft	0.93	0.96	0.75	1.18
Yield	kg/acre	1928	1695	1673	1614
Water Use Efficiency	kg/m^3	1.67	1.43	1.81	1.10
	kg/acre-ft	2073	1766	2230	1368

3.1.12 Fertilizer Use Efficiency

NPK levels on RCTs farms ranged from 69 to 72 kg/acre as compared to 81 kg/acre on non-RCTs farms. The efficiency of fertilizer at RCTs farms was greater because of the facts that these allow uniform distribution of fertilizer, which induces the farmers to use their less quantity. It was especially true in case of zero tillage and laser levelling. Data given in Table 23 show that at zero tillage and laser levelled farms, fertilizer use efficiency was almost the same. In case of zero tillage, fertilizers are placed close to seed. On precisely levelled farms distribution of fertilizers is more uniform. Higher fertilizer use efficiency showed that these technologies were more conducive to optimal use of fertilizer. This is followed by bed and furrow, and conventional methods of sowing.

Table 23*: Fertilizer Use Efficiency*

Technology	*No. of Farms*	*NPK (kg/acre)*	*Crop yield (kg/acre)*	*Fertilizer Use Efficiency(%)*
Zero Tillage	24	67.8	1871	27.59
Laser Levelling	10	71.8	1928	26.85
Bed and Furrow	5	68.6	1673	24.39
Conventional	32	80.8	1745	21.60

3.1.13 Comparison of Bed & Furrow Results with those of FESS Results

Results of a study conducted by (Kahlown *et al*., 1998) were compared to assess the authenticity of present findings in respect of bed & furrow. Yield and water use efficiency obtained at FESS farms are shown in Tables 24 and 25. Yield obtained on FESS Project were lower as compared to yield results of the present study. The yield difference is attributed mainly to comparatively more area under waterlogging and salinity in the FESS Project Area. The present study analyses the bed & furrow farms having width of 45 cm. Water use efficiency obtained at these farms was 1.81 which was slightly higher as compared to a comparable 70 cm bed at FESS Project. Water applied at FESS Project was 955 m^3/acre as compared to 923 m^3/acre in the area under study. FESS Project soils are comparatively sandy and porous in nature as compared to soils under RCTs farms. This is why crop water requirements at FESS soils were greater and hence depth of water applied was more and consequently WUE was lower.

Table 24: *Wheat Yield as Affected by the Methods of Irrigation and Water-Table Depth (1997-98)*

(kg/acre)

Method of Irrigation	*Water-table Depth (m)*			*Average Yield*
	0-1	*1-2*	*2-3*	
Bed 70 cm	1327	1688	1537	1517
Bed 95 cm	1396	1754	1570	1573
Bed 120 cm	1237	1673	-	1455

Source: Kahlown *et al*., 1998.

Table 25: *Water Use Efficiency as Affected by the Methods of Irrigation and Water-table Depth for Wheat (1997-98)*

Method of Irrigation	*Water-table Depth (m)*						*Average*
	<1		*1-2*		*2-3*		
	Water Applied (m^3/acre)	*WUE (kg/m^3)*	*Water Applied (m^3/acre)*	*WUE (kg/m^3)*	*Water Applied (m^3/acre)*	*WUE (kg/m^3)*	*WUE (kg/m^3)*
Bed 70 cm	663	2.00	1067	1.58	1135	1.35	1.64
Bed 95 cm	574	2.43	866	2.03	1063	1.48	1.98
Bed 120 cm	492	2.52	683	2.45	-	-	2.48

Source: Kahlown *et al*., 1998.

PART-II

In this part, analysis of data collected through 2nd survey by OFWM, Punjab is discussed as under:

3.2.1 Land Preparation and Sowing Cost

Soil preparation was mostly done by disc plough, rotavator and cultivator. These all implements were tractor driven. Some farmers also had disc harrows. Number of ploughing and planking practiced on surveyed farms are shown in Table 26. On zero tillage farms, no ploughing was done. However, on an average 1 planking was done on zero tillage farms. OFWM data had no information about cultural practices for wheat crop sown under laser levelling Technology, so data collected through 1st survey was used. On conventional farms, 5 Nos. of ploughing and 4 Nos. of planking was done.

Table 26: *Number of Ploughing and Planking on Wheat Farms 1999-2000*

Technology	*Ploughing*	*Planking*
Zero Tillage	-	1
Laser Levelling	4	2
Conventional	5	4

Zero tillage was the most cost effective method. On Zero tillage farms, land preparation and sowing cost was the lowest with Rs. 179 per acre. This is followed laser levelling with a cost of Rs. 900/acre and conventional with a cost of Rs. 955/acre (Table 27).

Table 27: *Land Preparation and Sowing Cost of Wheat 1999-2000*

(Rs./acre)

Technology	*Levelling*	*Ploughing*	*Planking*	*Sowing*	*Total*
Zero Tillage	-	-	50	129	179
Laser Levelling	190	500	100	110	900
Conventional	-	650	200	105	955

3.2.2 Sowing Period

The optimum time of planting wheat in rice-wheat cropping system of Punjab is 1-15 November. Farmers continue planting up to the end of December. One of the main reasons is that after harvesting of rice crop, the land preparation for wheat sowing is delayed. Wheat cultivation in such areas, if done with Zero Tillage saves sowing time by 15 days and reduces the cultivation cost to a considerable extent. No pre-sowing irrigation (*rauni*) is required in case wheat is planted in rice-harvested fields, because the crop is sown in residual moisture (*wad wattar*).

3.2.3 Seed Rate

Use of improved seed was much encouraging on sample farms. Most of the farmers used improved varieties of wheat. These included Inqilab 91, Wattan 94, MH 97, Punjab 96 and Pasban. Some farmers used seeds of these varieties retained from the previous crop. While the others used seed obtained from Government Seed Corporation and private companies. The survey revealed that Inqilab 91 was the most popular variety among the farmers. Table 28 shows that as the sowing time increased, quantity of seed rate increased. On an average seed rate used/acre on both improved and conventional farms was almost the same.

3.2.4 Irrigation

Sources of irrigation in the study area were canal and private tubewells. Conjunctive use of irrigation was common practice because canal supplies in the area are inadequate. On the farms of zero tillage, most of the farmers applied 3 irrigation with a depth of 3 to 4 inches each. On Laser Levelled farms, data showed application of 5 irrigations on an average with a depth of 2.5 to 3 inches per irrigation.

Table 28: *Sowing Dates and Use of Seed Rate for Wheat 1999-2000*

(kg/acre)

Sowing Time	*Seed Rate*		
	Zero Tillage	*Laser Levelling*	*Conventional*
4th week of Oct. to 1st week of Nov.	51	-	50
2nd week of Nov. to 3rd week of Nov.	52	50	51
4th week of Nov. to 1st week of Dec.	54	54	51
2nd week of Dec. to 3rd week of Dec.	59	60	60
Average	*54*	*55*	*53*

On conventional farms, an average of 5 irrigations were applied with a depth of 3-4 inches per irrigation (Table 29).

Table 29: *Number of Irrigations and Depth of Water Applied for Wheat 1999-2000*

Technology	*No. of Irrigations Applied*	*Range of Depth per Irrigation (inches)*
Zero Tillage	3	3-4
Laser Levelling	5	2.5-3
Conventional	5	3-4

3.2.5 Fertilizer

Use of commercial fertilizer was the common practice on sample farms. Farm yard manure (FYM) was applied to a limited extent. Data did not show about the use of green manuring on the sample farms. Use of nitrogenous fertilizers was much higher than the phosphate and potash fertilizers. Phosphate and potash fertilizers were applied as basal, while nitrogen was applied generally in two to three installments *i.e.*, with 1st, 2nd and 3rd irrigation. On zero tillage farms, NPK applied was about 85 kg/acre as compared to about 90 kg/acre in case of laser levelling. This difference of about 5 kg/acre might have played role in increasing yield on laser levelled farms compared to zero tillage farms. Yield obtained was 1754 and 1785 respectively. On non-RCTs farms, NPK applied was the lowest. In addition to non-adoption improved technology, lower fertilizer use per acre might have contributed to lower yield on these farms. Yield obtained on non-RCTs farm was 1456 kg/acre. NPK used for improved technologies and conventional farms is shown in Table 30.

Table 30: *Average Fertilizer Application for Wheat 1999-2000*

(kg/acre)

Technology	*N*	*P_2O_5*	*K_2*	*Total NPK*
Zero Tillage	48	35	0.7	84
Laser Levelling	47	39	3.3	89
Conventional	49	31	0.3	81

3.2.6 Plant Density

Plant densities of all planting techniques are presented in Table 31. Maximum plants were found under zero tillage followed by Laser Levelling and conventional. Tillers/m^2 and per plant were higher on laser leveled farm. This was due to better availability of soil moisture and ionic uptake of nutrients. On conventional farms, plants and tillers/m^2 were much lower than improved techniques. As compared to conventional farms, on zero tillage farms, tillers/plant were slightly lower but plants/m^2 and tillers/m^2 were higher. In case of laser levelling, all components of plant density were higher as compared to conventional farms.

Table 31: *Plant Densities under Different Sowing Techniques for Wheat 1999-2000*

Technology	*Plants/m^2*	*Tillers/m^2*
Zero Tillage	260	844
Laser Levelling	252	869
Conventional	238	794

3.2.7 Crop Yield

To evaluate the impact of RCTs on wheat yield, yield data was analyzed separately for each technology. A maximum yield of 1785 kg per acre was obtained from wheat crop sown on laser leveled farms. This followed Zero Tillage with 1754 kg per acre and conventional with 1486 kg per acre. However, the difference in yield between Zero Tillage and Laser Levelling was not significant while yield at RCTs farms was significantly higher than on conventional farms. Yield data is shown in Table 32.

Table 32: *Yield Statistics of Wheat 1999-2000*

(kg/acre)

Technology	*Yield*	*Percent increase over conventional*
Zero Tillage	1754	18
Laser Levelling	1785	20
Conventional	1486	-

3.2.8 Wheat Yield as Affected by Time of Sowing

Effect of sowing time both for RCTs and non-RCTs farms is shown in Table 33. The data show that as the time of sowing is delayed, the yield is decreased. On zero tillage farms, late sowing of wheat by about 2 weeks reduced yield in 2nd sowing period by 24 kg compared to 1st sowing period. In the 3rd sowing and fourth sowing period, it further decreased by 147 and 329 kg/acre.

Table 33*: Effect of Sowing Period on Wheat Yield*

(kg/acre)

Sowing Period	*Yield*					
	Zero Tillage	*Marginal decrease*	*Laser Levelling*	*Marginal decrease*	*Conventional*	*Marginal decrease*
4th week of Oct. to 1st week of Nov.	1879	-	-	-	1699	-
2nd week of Nov. to 3rd week of Nov.	1855	24	1910	-	1590	109
4th week of Nov. to 1st week of Dec.	1732	147	1770	140	1398	201
2nd week of Dec. to 3rd week of Dec.	1550	329	1675	235	1137	462

On laser levelled farms, the first sowing period started from 2nd week of Nov. to 3rd week of November. The yield obtained during this period was maximum. In the 2nd sowing, which lasted from 4th week of Nov. to 1st week of December, the yield decreased by 140 kg/acre compared to 1st sowing period. In the third sowing period, it further decreased. This decrease was 235 kg/acre as compared to 1st sowing period.

On conventional farms, yield decreased by 109 kg/acre in the 2nd sowing period as compared to 1st sowing period. In the 3rd sowing it further decreased by 201 kg/acre as compared to 1st sowing period. In the last and 4th sowing period, the decrease in yield was registered by 462 kg/acre. These results indicate that as the sowing period is delayed, yield/acre is reduced drastically.

3.2.9 Water Use Efficiency

Water use efficiency (WUE) is the ratio of crop yield and depth of water applied. It tells us how efficiently irrigation water has been used for crop production. Data given in Table 34 indicate that water use efficiency obtained on laser levelled and zero tillage farms was almost equal. However, depth of water applied on zero tillage farms was slightly lower. On conventional farms, water use efficiency was much lower than improved farms. Water saved on Zero Tillage and Laser Levelling amounted to 284 and 271 m^3/acre with a value of Rs. 210 and Rs. 200/acre respectively. Value of water saved was calculated based on private tubewell water charges as Rs. 900 per acre foot (AF) or Rs. 0.74 per m^3.

Table 34: *Water Use Efficiency of Wheat on Sample Farms*

Description	*Units*	*Zero Tillage*	*Laser Levelling*	*Conventional*
Water applied	m^3/acre	1268	1281	1552
	acre-ft	1.03	1.04	1.26
Yield	kg/acre	1754	1785	1456
Water Use Efficiency	kg/m^3	1.38	1.39	0.94
	kg/acre-ft	1703	1716	1156

3.2.10 Fertilizer Use Efficiency

NPK levels on RCTs farms ranged from 84.6 to 89.9 kg. The efficiency of fertilizer use at RCTs farms was greater than on conventional farms. Higher use of fertilizer at RCTs farms increased yield/acre. On non-RCTs farms, fertilizer level was lower. It might be one of the reasons of low yield at these farms in addition to non-adoption of RCTs. This table shows that fertilizer use efficiency was greater on Zero Tillage Farms, followed by Laser Levelling and Conventional Farms (Table 35).

Table 35: *Fertilizer Use Efficiency of Wheat 1999-2000*

Technology	*Total*	*Yield (kg/acre)*	*Fertilizer Use Efficiency (%)*
Zero Tillage	84	1754	20.7
Laser Levelling	89	1785	19.9
Conventional	81	1456	17.9

CHAPTER 4

ECONOMIC ANALYSIS

The economic analysis was aimed at evaluating the impact of Resource Conservation Technologies (RCTs) on land and crop productivity. The analysis was based on data collected from two field surveys. RCTs included in the first survey were zero tillage, laser levelling, bed planting methods for wheat 1999-2000 and use of mechanical method for transplanting of rice 1999. In the second survey RCTs included Zero Tillage and Laser Levelling.

4.1 Data Analysis

To evaluate the impact of these technologies, the primary input-output data collected from both the surveys were used. Impact evaluation of RCTs was based on deriving benefits through yields of rice and wheat obtained in 1999-2000. Gross benefits were calculated using the market prices of 1999-2000 for rice and wheat. For rice, gross income was calculated @ Rs. 450/40 kg and for wheat as Rs. 300/40 kg. Income from wheat by-product i.e., *bhoosa* calculated based on average prevailing rates in the study area as Rs. 50/40 kg were also included in gross benefits of this crop.

4.2 Cost of Crop Production

Farm costs represented the value of goods and services utilized in agricultural production. Money values were assigned to all input items using farm gate or market prices for the survey year 1999-2000. The cost per acre of production for rice and wheat is shown in Tables 36 and 37, respectively. Table 36 shows that cost of production on mechanical rice farms was higher than on non-mechanical farms. The reason was high cost of nursery transplanting by machine.

Table 36*: Cost of Production for Rice1999*

(Rs./acre)

Technology	*Fixed Cost**	*Variable Cost***	*Total Cost*
Mechanical	5050	1200	6250
Manual	5050	500	5550

*Fixed cost included cost on cultural practices, seed, fertilizers, irrigation and harvesting/threshing.

**Variable cost included cost of nursery and transplanting.

It is shown in Table 37 that zero tillage technique of wheat sowing is the most cost effective method with total cost of production (COP) being Rs. 3805 per acre. The main reason for low-cost of production for this particular technology was low cost of land preparation. Bed and furrow was the second cost effective method with cost of production as Rs. 4233 per acre. The main reason for low cost of this method was the less expenditure incurred on weedicide and irrigation. Cost of production for laser levelling was higher than other improved sowing techniques. The cost difference was attributed mainly to cost of levelling on conventional farm COP was the highest.

Crop production analysis of wheat based on OFWM data is given in Table 38. On farms, where wheat was sown with zero tillage, cost of production was lower than wheat sown on laser levelled farms or conventional farms. OFWM data had no or ambiguous information on land preparation and sowing cost of laser levelled farms, so data collected from first survey was included to calculate cost of production for this technology.

Table 37: *Cost of Production for Wheat by Type of Technology*

(Rs./acre)

Technology	*Levell-ing*	*Seed*	*Ploug-hing*	*Plank-ing*	*Sow-ing*	*Irriga-tion*	*Ferti-lizer*	*Weed-icide*	*Harvesting/ Threshing*	*Total cost of produc-tion*
Zero Tillage	-	381	-	50	114	388	1181	332	1369	3805
Laser Levelling	190	386	426	100	110	306	1172	480	1380	4550
Bed & Furrow	-	375	500	100	250	249	1148	300	1311	4233
Conventional	-	373	616	182	65	527	1428	406	1426	5022

Table 38*: Cost of Production for Wheat 1999-2000*

(Rs./acre)

Technology	*Levell-ing*	*Seed*	*Ploug-hing*	*Plank-ing*	*Sow-ing*	*Irriga-tion*	*Ferti-lizer*	*Weed*	*Harvesting/ Threshing*	*Total Cost*
Zero Tillage	-	540	-	50	129	386	1485	316	1362	4248
Laser Levelling	190	616	500	100	110	366	1610	300	1380	5172
Conventional	-	530	650	200	105	516	1396	316	1190	4903

4.3 Gross Benefits

Gross benefits of rice and wheat were calculated by multiplying yields with market prices of respective crops for the year 1999-2000. Gross income for wheat also included gross benefits of wheat *bhoosa*. Gross per acre return analysis based on data from first survey for rice and wheat is shown in Tables 39 and 40 respectively. Gross benefits were slightly higher with mechanical rice planting compared to non-mechanical method of sowing rice (Table 39). Gross benefits were higher with laser levelling followed by zero tillage and conventional farms. Bed & furrow had the lowest gross benefits (Table 40).

Table 39: *Per Acre Benefit-Cost Analysis of Rice 1999*

Technology	*Cost (Rs.)*	*Gross Benefit (Rs.)*	*Net Benefits (Rs.)*	*B. C. Ratio*
Mechanical	6250	14681	8431	1.35
Manual	5550	14591	9041	1.63

Table 40: *Per Acre Benefit-Cost Analysis of Wheat 1999-2000*

Technology	*Cost (Rs.)*	*Gross Benefit (Rs.)*	*Net Benefits (Rs.)*	*B. C. Ratio*
Zero Tillage	3805	16371	12566	3.30
Laser Levelling	4550	16870	12320	2.71
Bed and Furrow	4233	14639	10406	2.46
Conventional	5022	15279	10257	2.04

Gross benefit analysis for wheat based on OFWM data is shown in Table 41. This showed higher gross benefits on laser levelled farms followed by zero tillage and conventional farms.

4.4 Net Benefits

Economic well being and farming success depends mainly upon realized net income. Gross income is a monetary measure of total production. To accomplish this production, quantities of various goods and services were utilized. A higher gross income resulting from a high cost of production is no better than a low gross income having a low expenditure alternative. A high portion of the income may be offset by corresponding higher costs of production. Therefore, it is the net income which is the final important attribute. Net benefits were computed by subtracting production costs from gross income. Net income result analysis based on data from first survey for rice and wheat is shown in Tables 39 and 40 respectively. Net benefit analysis for wheat based on OFWM data are shown in Table 41. Net Benefits were higher in case of zero tillage followed by laser levelling and conventional farms. Table 40 shows that for wheat 1999-2000 net benefits were higher from zero tillage followed by laser levelling and bed & furrow farms. Net benefits obtained from conventional method were the lowest. Table 39 showed that net benefits on mechanical rice farms were lower than on non-mechanical farms.

4.6 Benefit-cost Analysis

Benefit-cost (BC) analysis is an appropriate measure to evaluate the project usefulness. This analysis determines whether the project was economically feasible and the resources optimally invested. To establish the economic feasibility of a project, it is imperative that the resulting gains in the value of benefits be compared with the project cost. This analysis involves the assessment of the effects by RCTs technique on wheat productivity. The approach adopted measures the project benefits accrued in the form of the net product value and costs incurred.

Benefit-cost ratios have been estimated for each technology to establish its economic feasibility. Benefit-cost analysis for rice showed that net benefits were higher on rice farms transplanted by manual method. The reason was low cost of production while yields obtained on mechanical and manual farms were almost equal. So, non-mechanical rice sowing for the year 1999 on sample farms remained economically more feasible than mechanical sowing of rice (Table 39).

Benefit-cost analysis for wheat based on data from 1st sowing showed that Zero Tillage Method was economically the most feasible and attractive option for farming community. The second economically most feasible technology was sowing of wheat on precisely levelled fields. This followed by Bed & Furrow Method with B. C. ratio of 2.46. Non RCT (conventional) Method had the lowest BC ratio of 2.04 (Table 40).

BC ratios calculated based on wheat data by OFWM showed the same trend. Zero Tillage was economically the most feasible with B. C. ratio of 2.61 followed by Laser Levelling with BC ratio of 2.02. Sowing of wheat by conventional techniques had the lowest BC ratio of 1.60 (Table 41).

Table 41*: Per Acre Benefit-Cost Analysis of Wheat 1999-2000*
(Based on OFWM Data)

Technology	*Cost (Rs.)*	*Gross Benefit (Rs.)*	*Net Benefit (Rs.)*	*B. C. Ratio*
Zero Tillage	4248	15347	11099	2.61
Laser Levelling	5172	15619	10447	2.02
Conventional	4903	12740	7837	1.60

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions were drawn from this analysis:

- Land preparation and sowing cost/acre of zero tillage farms was significantly less than conventional farms. On zero tillage farms, the cost ranged from Rs. 164 to 179/acre, while on conventional farms, it ranged from Rs. 863 to Rs. 900/acre.
- Seed rate used on RCTs farms was slightly lower as compared to non-RCTs farms. Moreover, the efficiency of fertilizer use was greater on RCT farms as compared to conventional farms. On zero tillage, laser levelling, bed & furrow and conventional farms, average fertilizer use efficiency was 24, 23, 24 and 20, respectively.
- On an average 0.30 AF of water per acre could be saved by adopting zero tillage technology besides saving a pre-sowing irrigation. Moreover, significant quantity of water could be saved by adopting laser land levelling & bed and furrow method of wheat sowing.
- Weed density with bed & furrow was the minimum followed by zero tillage and laser levelling. On conventional farms, plant density was the highest. Plant density on RCTs wheat farms ranged from 75 to 131 plants/m^2 against 104 plants/m^2 on non-RCTs farms.
- Soil salinity increased slightly with zero tillage because of low water application after harvesting of high delta rice crop. However, this salinity was not seriously affected by wheat sowing methods and remained within safe limits. Moreover, zero tillage gave better results in improving the soil fertility due to decomposition of rice stubbles. The infiltration rate of soil by using zero tillage technique was also 43 percent greater than traditional sowing method.
- Average yield/acre for wheat crop in case of laser levelling was the highest with 1856 kg/acre followed by zero tillage with 1812 kg, bed & furrow with 1673 kg and conventional farms with 1615 kg/acre.
- In mechanical rice transplanting, 96 percent less man-hours were required as compared to manual or conventional transplanting. Two acres of rice can be transplanted by mechanical transplanter as compared to one acre by manual transplanting during the same time. Reduction in sowing time and labour was the main benefit of mechanical transplanting. Yield per acre on mechanical rice farms was 1305 kg, whereas it was 1297 kg/acre on manually transplanted fields.

5.2 Recommendations

- Benefits of RCTs farms can be increased and sustained through better irrigation agronomy. Extension services should be strengthened to disseminate the results of RCTs among the farming community.
- Government should provide necessary facilities for the promotion of RCTs. Moreover, the quality of farm implements used for RCTs should also be ensured. Necessary improvement/modification in equipment can help increase their efficiency.

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Annexure-I

QUESTIONNAIRE FOR THE
EVALUATION OF RESOURCE CONSERVATIVE TECHNOLOGIES (RCTs)

1. The Farm

Name____________________________________ s/o __________________________________

Education __________________________ Village/District ____________________________

Location of Farm: Head _________ Middle _____________ Tail___________________

2. Watercourse

Lined: Yes _________ No __________

if Yes, Years of Improvement: _____________

Length: _______________

Type of construction _______________________

Land Preparation and Sowing (Cost/Acre)

Technology	*Land Levelling*	*Ploughing*	*Planking*	*Sowing*
Zero Tillage				
Laser Levelling				
Bed and Furrow				
Conventional				

Area under Technology and Expenditure

Technology	*Area (acre)*	*Period/Season*	*Cost (Rs./acre)*
(a) Laser levelling			
(b) Zero tillage			
(c) Furrow and bed shaper			
(d) Combination			
(e) Conventional			
(f) Laser			
(g) Any other			

Cropping Pattern

Kharif crops ____

Rabi crops ____

Plant Density

Seed Rate ___________ Variety____________ Plant density _________

No. of Tillers _________________________

Stem Borer Infestation

Insect incidence on previous crop:

Type of insects ________________

Control measure applied

If yes, method of control

Cultural _________________

Mechanical ________________

Chemical __________________

If chemical, name of chemical _______________

Dose per acre ___________________________

Cost per acre __________________________

Weed Infestation

Weed density per Sq. m. ________

Control: Mechanical _______ Weedicide _______

If weedicide applied then, Type _____ Qty. _______ Cost acre ____

Type of weeds:

(i)

(ii)

(iii)

Harvesting/Threshing

Date _____________________ Manual/Machine ___________________________

Harvesting __________ Threshing cost _______________

Soil analysis

Salinity:	pH	EC_e,	SAR	
Fertility:	N	P	K	Organic matter

Farmers' perception on improved technology.

Irrigation (per acre)

Source	Zero Tillage				Furrow and Bed Shaper				Laser				Conventional			
	Q (cfs)	Time (hr)	No. of Irrigat.	Cost/ Acre	Q (cfs)	Time (hr)	No. of Irrigat.	Cost/ acre	Q (cfs)	Time (hr)	No. of Irrigat.	Cost/ acre	Q (cfs)	Time (hr)	No. of Irrigat.	Cost/ acre
Canal																
T/well																
Canal+T/well																
Alternate																

Fertilizer

Type	Zero Tillage			Furrow and Bed Shaper			Laser			Conventional		
	Application Time	Rate kg/acre	Cost/ acre	Application Time	Rate kg/acre	Cost/ acre	Application Time	Rate kg/acre	Cost/ acre	Application Time	Rate kg/acre	Cost/ acre
Chemical												
(i)												
(ii)												
(ii)												
FYM												
Pressmud												

Yield

Zero Tillage			Furrow and Bed Shaper			Laser			Conventional		
Grain (kg/acre)	No. of Grains/ Spike	*Bhoosa*/ acre	Grain (kg/acre)	No. of Grains/ Spike	*Bhoosa*/ acre	Grain (kg/acre)	No. of Grains/ Spike	*Bhoosa*/ acre	Grain (kg/acre)	No. of Grains/ Spike	*Bhoosa*/ acre