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Research Article

Water Use Efficiency Under Different Rice Cultivation Practices in Rice-Wheat System of Pakistan

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2. Keywords

Paddy yield; Water productivity; Basmati rice; Bed-furrow; Double zero tillage

1. Abstract

Water shortage is a major concern to increase or sustain productivity of the rice-wheat system. There is an emerging need to adapt improved production technologies and irrigation management practices to increase per acre yield and water productivity. The crop establishment technologies/cultivation practices like double zero tillage and bed planting for rice and wheat, zero tillage for wheat and direct seeding for rice were evaluated at PARC Farm, Kala Shah Kaku (KSK) and Muridke by conducting experimentation during period of three years. Water use recorded for Basmati rice at KSK under double zero tillage, direct seeding of rice, bed-furrow and conventional method of plant establishment was 1049, 1115, 1256 and 1392 mm respectively. Crop establishment practices of double zero tillage, direct seeding and bed planting saved irrigation water by 30, 25 and 12% as compared to conventional practice. Paddy yield recorded under double zero, direct seeding, bed-furrow and conventional practices was 3.81, 3.93, 3.83 and 4.10 ton/ha respectively. Water productivity of 0.36, 0.35, 0.31 and 0.29 kg/ $m^3$was found under double zero, direct seeding, bed-furrow and conventional practices respectively. The Basmati rice gown on farmers' field at Muridke using direct seeding technique gave paddy yield of 4.5 t/ha as compared to 3.7 t/ha under conventional method, which is 22% higher than the conventional method. Where as, the direct seeding did not save any irrigation water. Water productivity under direct seeding was 15% higher than conventional rice transplantation method.

3. Introduction

Rice and wheat are the two major cereal crops substantially contributing to human diet as well as livestock feed requirements in the world [1]. In Pakistan, rice-wheat production system is adopted on 2.5 million hectares (M.ha), i.e., about 12% of total farm land [2]. Average per hectare rice and wheat yields in the country are 2.2 tons and 2.45 tons respectively, however, progressive farmers are gaining 4.58 and 4.5 tons per hectare of yields of rice and wheat crops. Rice and wheat are important staple food crops in Pakistan. They are hardly meeting the food requirement of the country. In order to meet the food demand of increasing population in the country, crop production will have to increase accordingly.

The efficient use of water is essential to address increasing demands for water and environmental concerns. Agriculture is the major user of water, thus irrigation systems should be planned, designed and operated efficiently [3]. In Pakistan, irrigation practices are based on traditional methods. Provision of adequate control of water and proper land preparation to permit uniform distribution of water over the field are the two importance factors to obtain high efficiency in surface irrigation [4]. To improve this supplying efficiency of water in fields, [5] have put emphasis on the input and output study towards the field. The lower Bari Doab command area was set to observation by [6]. to check the grain productivity per unit water. A small canal command area of Jandraka was selected for evaluation study with the help of a questionnaire survey. The average rice yield at Jandraka was 2,606 kg/ha, whereas the average water productivity was 0.08 kg/ m^3. The rice crop had its potential of 710 mm but it was irrigated with 2,936 mm water. It is vital for food security to acquire more rice within limited water resources [7]. In order to achieve a goal of Resource Conservation Technologies (RCTs), the local and international organizations are trying to urge people to decrease their water consumption and get more production efficiently. The methods of laser land leveling and zero tillage are mostly being adopted as RCTs in sugarcane-wheat and rice-wheat cropping systems of Pakistan [8]. Different field experimentations have proved to be successful about these technologies in saving the water and making its use to irrigate the field efficiently [9-11]. An assessment of direct seeding of rice and making bed of rice have shown a considerable success to the goal of saving water. But a drawback that didn't prove this technology widely accepted by farmers was the low output production than the conventional

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methods of farming. For this, more steps are to be taken in accordance with removing of weeds, drilling machinery and introduction of farmer to perform time to time agronomic operation [12].

There a number of differences were found between input water and requirement of water by wheat and rice in field study of old methods of irrigation. The demand of water for rice was 532 mm but it was applied as 1458 mm. This shows that 60% of water was wasted at root zone in form of percolation and seepage only 40% of that was used in form of evapotranspiration. The water productivity for rice is only 0.23 kg/m^3, i.e., one kilogram rice is produced by 4.35 m^3 of water. Study on different sample farms exhibit a great difference in water productivities as for rice 0.19-0.32 kg/m^3 and for wheat 0.93-1.39 kg/m^3. These variations are due to change in agricultural and water management techniques while climate, soil and water properties were same. It was noticed from the results of four sample water channels that areas having more alternating crops in a season and have more usage of laser land leveling and zero tillage, have more water productivities [12,13] assessed water productivity of rice and wheat crops using alternative crop establishment techniques. This also found that conservation technique of directly drilling rice saved 25% of water instead of old practices of transplanted puddled rice and also increased in water productivity with a range of 0.27 to 0.32 kg/m^3. Because of extensive weeds growth, there was a loss in total output in operation of zero tillage and direct drilling. Zero tillage is proving better than the conventional practices whereas bed planting needs improvement in terms of land (4.3 t/ha) and water productivity(1.6 kg/m^3).

Water scarcity is the main hurdle in increasing the output yield of rice-wheat crop. As the water yield in Pakistan is failing to match the increasing demand by different crops in agriculture [14]. There would be decline in availability of fresh water for agriculture use owing to increased industrial, environmental and domestic demands. The production of more food with less water will be a challenge for agriculture in 21st century. As 50% of freshwater in Asia is used in production of rice, it is necessary to use it efficiently [15]. The only solution to this water scarcity problem is to produce more rice with less water [16].

The shortfall can be met either by constructing new storage reservoirs or by improving the efficiency of the existing water use practices. Both are equally important however, the construction of new storage reservoirs requires huge financial investment along with other constraints such as: limited availability of potential sites, population displacement, environmental, and socio-political issues. Therefore, proper management of existing water resources appears to be an immediate option. Under the present water scarcity conditions, it becomes even more important to use water judiciously and increase the water productivity [17-19]. Some of the researchable issues confronted in the area include:

- Quantification of irrigation water being applied under different cultivation practices such as direct seeding, zero tillage, double zero tillage, raised bed and conventional methods.
- Which conservation technologies are water efficient?
- Determination of water savings and water productivity under different cultivation practices for rice in rice-wheat cropping system

Adoption of crop establishment technologies like direct seeding for rice and zero tillage for wheat, bed planting and double zero tillage for rice and wheat are expected to be resulted in enhanced crop production and water savings. Additionally, it is hoped they will also address issues related to poverty, labor shortages and environment [8]. There is a need to study the impacts of these technologies on increase in crops yield and saving in water

Research studies were conducted at the PARC Farm, Kala Shah Kaku and Farmers' Fields at Muridke to assess different cultivation practices and strategies of irrigation management in order to increase per acre yield and water-productivity of the crops. The crop establishment technologies evaluated under the project for rice crop are, the double zero tillage, bed planting, direct seeding and conventional method. The studies on rice crop have been completed for two seasons.

4. Methodology

The study area lies in the rice-wheat cropping system of Pakistan (Figure 1). The experiments on rice crops were conducted during the year 2008 and 2009 on two locations, i.e., a. PARC Farm, Kala Shah Kaku and b. Farmer's Field, Muridke. Following treatments had been used in the study.

- Double zero tillage (for Kala Shah Kaku)
- Direct seeding
- Bed planting
- Conventional sowing

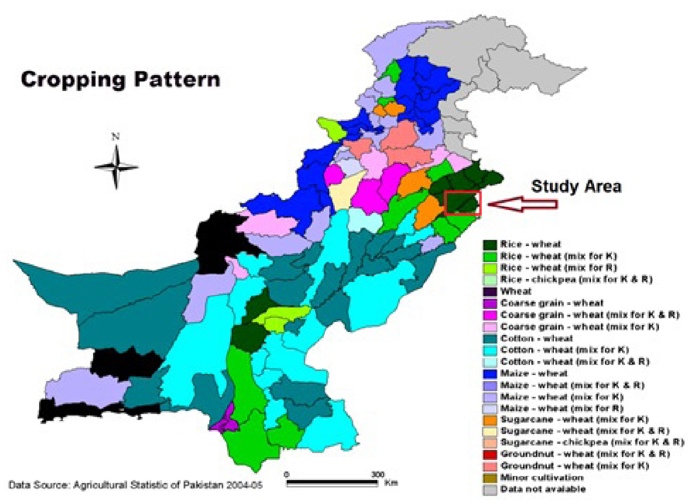

Figure 1: Location of the study area in Pakistan

4.1 Site Selection and Characterization

Site for experimentation of resource conservation technologies during the first year of the project was selected at the farm land of PARC Rice Programme, Kala Shah Kaku, Lahore. The site is located at longitude of 74.26 E, latitude of 31.72 N at altitude of about 201 m. Tube well water and canal is available for irrigation. Water conveyance system consist of pacca and earthen water courses and diversion structures (naccas). Soil texture and bulk density of experimental site was determined. Soil samples were taken from 0-15 cm and 15-30 cm depths after harvesting of rice crop in 2007 for Kala Shah Kaku Farm. Composite sample was used for textural analysis. During the 2nd year another site was selected at Muridke to conduct research on farmer's field and the soil data was collected after harvesting of the wheat crop in 2009.

4.1.1 Measurement of Infiltration:

Irrigation is mainly influenced by the infiltration characteristics of soil. Infiltration rate and accumulated infiltration are the two parameters commonly used in evaluating the infiltration characteristics of soil. The measurement of infiltration was carried out at Kala Shah Kaku after harvesting of rice crop during 2007. The double ring infiltrometer was used for measurement of infiltration characteristics of the soil. The accumulated infiltration and infiltration rate were measured for four plots under four treatments namely the double zero tillage, Zero tillage/ direct seeding, furrow-bed and conventional method.

4.2 Design and Layout of Field Experiment

Evaluation of RCTs: At KSK experimental design for wheat and rice consists of four treatments. Each treatment replicated three times. Size of each plot is 25 x 10 m and there are 12 plots in total. Experimental layout is given in (Figure 2) and (Figure 3). It consists of location of tube well, pacca and earthen watercourses, diversion structures (Naccas), experimental treatment/replication plots and farm dimensions and farm road. The layout is complete randomized design. At Muridke there were two treatments namely the direct seeding and conventional method. The plot size under each treatment is one acre.

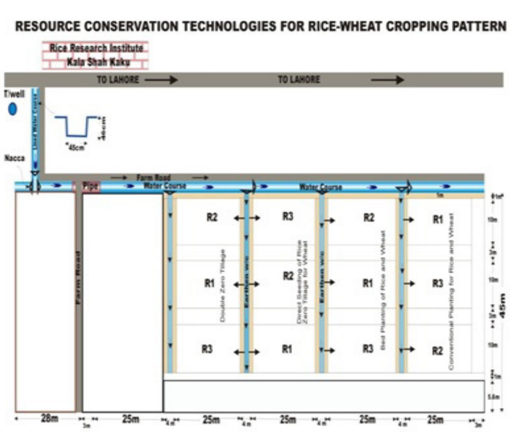

Figure 2: Layout of Experimental plots and irrigation channels

Figure 3: Pictorial Layout of Experimental plots and irrigation channels

4.3 Land Preparation

Kala Shah Kaku:

Land preparation operations were performed for the treatment of bed planting, direct seeding and conventional. For double zero tillage no land preparation operation was performed. The plots for bed planting were ploughed four times and planking was performed two times. The plots for direct seeding were ploughed four times with two planking. The plots for treatments of saturation, alternate wetting and drying and conventional planting were ploughed six times and planking was performed three times. The bed was formed with bed shaper.

Muridke:

Land preparation operations were performed for the treatments of direct seeding and conventional planting. The fields for direct seeding were ploughed four times with two planking. The field for treatments of conventional planting was ploughed six times and planking was performed three times.

4.4 Sowing and Harvesting

Kala Shah Kaku:

Rice variety basmati (Supper- line 4048) was sown and transplanted during 2008 at KSK. The nursery was sown on 10-06 2008. The direct seeded rice was sown on 11-06-2008. Transplanting of rice was performed on 15-07-2008 under double zero, bed and conventional treatments. Harvesting was performed on 16-11-2008. The direct seeded rice was sown in well prepared soil at water condition with zero till drill by applying seed at the rate of 10 kg/acre. Two rows of rice were transplanted on bed with plant to plant spacing of 6 inch. Rice on plot of double zero tillage was transplanted randomly with approximate spacing of 20 x 20 cm.

During 2009 rice variety basmati (Supper) was sown and transplanted at KSK. The nursery was established on 05-06 2009. Direct seeding was done on 07-06-2009. Transplanting of rice was performed on 10-07-2009 under double zero, bed and conventional treatments. Rice crop was harvested from all treatments on 10-11-2009. The direct seeded rice was sown in well prepared soil at water condition with zero till drill by applying seed at the rate of 10 kg/

acre. Two rows of rice were transplanted on bed with plant to plant spacing of 6 inch. Rice on plot of double zero tillage was transplanted randomly with approximate spacing of 20 x 20 cm.

Muridke:

Rice variety basmati (Supper) was sown and transplanted at Muridke during 2009. The rice nursery for kharif 2009 was established on 1-06-2009. Direct seeding was performed using drill machine on 12-06-2009. Rice under treatment of conventional method was transplanted on 14-07-2009. Rice crop was harvested from both the treatments on 10-11-2009. The direct seeded rice was sown in well prepared soil at water condition with zero till drill by applying seed at the rate of 12 kg/acre.

4.5 Fertilizer Application

The recommended fertilizer rate of 130:80:60 kg/ha was applied (DAP = 1.5 bag, Potash = 1 bag and Urea = 2 bags). Potash and DAP was applied at the time of sowing to all the treatments. Fertilizer application was done using drill for direct seeding; whereas, it was broadcasted for bed, double zero and conventional treatments. Two third of the urea under treatment of bed , double zero, conventional , saturation and alternate wetting and drying was applied after 20 days of transplanting, whereas, one third was applied 50 days after transplanting. Under direct seeded rice two third of the urea was applied after 30 days of sowing, whereas, one third was applied after 55 days after sowing.

4.6 Climatic Data

The historic climatic and real time rainfall data was collected to meet the experimental requirement. The climatic data was required for computation of reference crop evapotranspiration (ETo). Different method for calculating ETo requires different climatic and physical parameters. Historic climatic data for closest place to Kala Shah Kaku, i.e., Lahore meteorological center was acquired. The climatic data on maximum temperature, minimum temperature were available for the period from 1931 to 2006. The data on sunshine hours and wind speed were available for the period from 1951-2000 and 1942-2000 respectively, while, the data of wet and dry bulb temperatures were available for the period from 1933-2000.

Rainfall received during rice growing period at Kala Shah Kaku is given in (Table 1). Total rainfall received during 2008 at KSK is 227.5 mm. whereas rainfall received during 2009 at KSK is 282.2 mm

4.7 Irrigation Water Measurement

Source of irrigation water at Kala Shah Kaku was both canal and Tube well water. Cut throat flume of 3′ x 4″ size was permanently installed for measurement of water discharge at Kala Shah Kaku. Time of irrigation and corresponding upstream and downstream water heads were recorded for each plot. Submerged flow was observed and computation for determination of water discharge was made accordingly. Source of irrigation water at Muridke was electric operated tube well. Size of delivery pipe was 5 inch. Tube well discharge was measured by installing cut throat flume of 3′ x 4″ size. Time of irrigation was noted for each field and every irrigation R-factor value was then derived in ArcGIS using the following equation:

Table 1: Rainfall during rice growing period at Kala Shah Kaku

2008		2009	
Date	**Rainfall (mm)**	**Date**	**Rainfall (mm)**
12/7/2008	81.6	19-7-09	61.7
13-7-08	10.8	23-07-09	33.9
20-7-08	9.8	24-07-09	26.2
21-7-08	17.3	28-07-09	77.1
5/8/2008	4.4	1/8/2009	18.5
6/8/2008	13.9	18-08-09	34.3
12/8/2008	29	3/9/2009	30.5
13-08-08	40.1	**Total**	**282.2**
15-08-08	4.6		
5/9/2008	13.3		
23-09-08	2.7		
Total	**227.5**		

4.8 Physical Soil Characterization and Soil Moisture Movement

Soil characteristics were determined at the two target sites for textural classification. Soil samples were taken after harvesting of rice crop at Kala Shah Kaku in 2007. Textural analysis for Kala Shah Kaku site is given in (Table 2). Soil texture of all plots is silty clay and bulk density is 1.35 gm/cm^3. Soil samples from Muridke site were taken after harvesting of wheat crop in 2009. Textural analysis for Muridke site is given in (Table 2). Soil texture of all plots is silt loam. Bulk density is 1.42, 1.44 and 1.4 gm/cm^3 for experimental plots of zero tillage/direct seeding, bed-furrow and conventional method respectively.

Table 2: Soil texture at Kala Shah Kaku and Muridke

Kala Shah Kaku					
Treatment	**Clay %**	**Silt %**	**Sand %**	**Texture**	**Bulk Density (gm/cm3)**
Double Zero Tillage	42.4	54	3.6	Silty Clay	1.35
Zero Tillage Direct Seeding	46.4	50	3.6	Silty Clay	1.35
Bed	46.4	52	1.6	Silty Clay	1.35
Conventional	42.4	54	3.6	Silty Clay	1.35
Muridke					
Zero Tillage/Direct Seeding	19	53.8	27.2	Silt Loam	1.42
Bed-furrow	23	50.8	26.2	Silt Loam	1.44
Conventional	25	58.2	16.8	Silt Loam	1.4
(Avg. of 0-15 and 15 – 30 cm					

4.9 Determination of Potential Crop evapotranspiration

Potential crop evapotranspiration (ETc) is a measure of water required by the crop through evaporation form the surface and transpiration from the crop under the condition when there is no stress of water and disease to crop. Determination of ETc is required to plan irrigation scheduling. Historic climatic data collected from Lahore station was used for determination of ETo for wheat and rice growing period. The reference crop evapotranspiration (ETo) for rice growing period was computed using Modified Penman Method. Crop coefficient (Kc) values suggested as in irrigation and drainage paper by FAO was opted for computation of Crop Evapotranspiration.

The computed ETc values for rice crop are given in the (Table 3). Water requirement for rice crop during the month of July and August is 6.07 and 6.14 mm/day, which shows that it is higher at the initial stage. Water requirement for rice crop during the month of November is 1.68 mm/day. Which shows that water requirement for rice crop at harvesting stage is significantly less than the initial stage. Total water requirement for the whole rice growing period amounts to 600 mm. Average amount of water applied to rice experimental crop under conventional method at Kala Shah Kaku is 1392 mm against the water requirement of 600 mm. It shows that 793 mm of water applied to rice crop was deep percolated and not used by the crop.

Table 3: Potential Crop Evapotranspiration (ETc) for Rice Crop at Kala Shah Kaku, Lahore

Month	ETo mm/day	Kc values	ETc mm/day	ETc mm/month
July (16 days)	5.78	1.05	6.07	92
August	5.12	1.2	6.14	190
September	4.65	1.25	5.81	174
October	3.02	1.25	3.78	117
November (16 days)	1.6	1.05	1.68	27
Total				**600**

5. Results and Discussion

5.1 Water use and Water savings at Kala Shah Kaku

Summarized data on water amounts applied during 2008 to rice crop at Kala Shah Kaku under different resource conservation technologies is given in (Table 4). The result shows that irrigation application under double zero tillage, direct seeding of rice, bed-furrow and conventional method of cultivation was 846, 791, 1099 and 1243 mm respectively. Rainfall received during crop growing season under direct seeding was 248 mm, whereas it was 228 mm in case of other three treatments. Total water used by rice crop including rainfall was 1073, 1038, 1327 and 1471 mm under double zero tillage, direct seeding of rice, bed-furrow and conventional method respectively. Direct seeding of rice, double zero tillage and bed-furrow method saved 36, 32 and 12 % of water respectively as compared to conventional method.

Summarized data on water amounts applied during 2009 to rice crop at Kala Shah Kaku under different resource conservation technologies is shown in (Table 5). Irrigation application under double zero tillage, direct seeding of rice, bed-furrow and conventional method of cultivation was 742, 910, 903 and 1032 mm respectively. Rainfall received during crop growing season was 282 mm under all treatments. Total water used by rice crop was 1024, 1192, 1185 and 1314 mm under double zero tillage, direct seeding of rice, bed-furrow and conventional method respectively. Double zero tillage, direct seeding of rice and bed-furrow method saved 28%, 12% and 12% of water respectively as compared to conventional method.

Average values of water use for two growing season during 2008 and 2009 under different RCTs are given in (Table 6). Irrigation water applied to rice crop under treatments of double zero tillage, direct seeding, bed planting and conventional sowing was 794, 850, 1001 and 1137 mm respectively. Rainfall received during crop growing season under direct seeding was 265 mm, whereas it was 255 mm in case of other three treatments. Total water used by rice crop was 1049, 1115, 1256 and 1392 mm under double zero tillage, direct seeding of rice, bed-furrow and conventional method respectively. Crop establishment practices of double zero tillage, direct seeding and bed planting saved irrigation water by 30%, 25% and 12% as compared to conventional practice.

Table 4: Water Application and Water Savings for Rice Crop Under Different RCT at Kala Shah Kaku During 2008

Treatment	Irrigation water Applied (mm)	Irrigation Water Saving %	Rainfall (mm)	Total water Application (mm)
Double Zero Tillage	846	32	228	1073
Direct Seeding	791	36	248	1038
Bed-Furrow	1099	12	228	1327
Conventional	1243	0	228	1471

Table 5: Water application and water savings for rice crop under different RCTs at Kala Shah Kaku during 2009

Treatment	Irrigation Water Applied (mm)	Irrigation Water Saving in%	Rainfall (mm)	Total water Application (mm)
Double Zero Tillage	742	28	282	1024
Direct Seeding	910	12	282	1192
Bed Furrow	903	12	282	1185
Conventional	1032	0	282	1314

Table 6: Average water application and water savings for rice crop under different RCTs at Kala Shah Kaku during 2008 and 2009

Treatment	Irrigation Water Applied (mm)	Rainfall (mm)	Total water Application (mm)	Irrigation Water Saving in%
Double Zero Tillage	794	255	1049	30
Direct Seeding	850	265	1115	25
Bed-Furrow	1001	255	1256	12
Conventional	1137	255	1392	0

5.2 Paddy yield and water productivity at Kala Shah Kaku

Paddy yield obtained during 2008 and 2009 at Kala Shah Kaku under different treatment is given in the (Table 7) and (Table 8) along with corresponding water application and water productivity. Water application includes the irrigation water and rainfall. The result shows that the paddy yield during 2008 was 4.31, 3.93, 3.9 and 4.4 ton/ha under double zero, direct seeding, bed-furrow and conventional methods. Water used by the rice crop was 1073, 1038, 1327 and 1471 mm under double zero, direct seeding, bed-furrow and conventional methods. During 2009 paddy yield was 3.30, 3.93, 3.77 and 3.80 ton/ha under double zero, direct seeding, bed-furrow and conventional methods. Whereas, water used by the rice crop was 1024, 1192, 1185 and 1314 mm under double zero, direct seeding, bed-furrow and conventional methods.

Average values of paddy yield and water productivity for two growing season during 2008 and 2009 are given in Table 9. Paddy yield recorded under double zero, direct seeding, bed-furrow and conventional practices was 3.81, 3.93, 3.83 and 4.10 ton/ha respectively. Water productivity of 0.36, 0.35, 0.31 and 0.29 kg/m^3 was found under double zero, direct seeding, bed-furrow and conventional practices respectively.

Table 7: Paddy yield and water productivity for rice crop under different RCTs at Kala Shah Kaku during 2008

Treatment	Paddy Yield (Ton/ha)	Total water Application (mm)	Water Productivity (kg/m3)
Double Zero Tillage	4.31	1073	0.4
Direct Seeding	3.93	1038	0.38
Bed-Furrow	3.9	1327	0.29
Conventional	4.4	1471	0.3

Table 8: Paddy yield and water productivity for rice crop under different RCTs at Kala Shah Kaku during 2009

Treatment	Paddy Yield (Ton/ha)	Total water Application (mm)	Water Productivity (kg/m3)
Double Zero Tillage	3.3	1024	0.32
Direct Seeding	3.93	1192	0.33
Bed-Furrow	3.77	1185	0.32
Conventional	3.8	1314	0.29

5.3 Water Use and Water Savings at Muridke

Basmati rice was grown using conventional and direct seeding methods of crop establishment at Muridke. Irrigation was applied using electric operated tube well. Summarized data on water amounts applied during 2009 to rice crop under direct seeding and conventional treatments is given in (Table 10). Irrigation water applied under direct seeding and conventional method of sowing was 1197 and 1138 mm respectively. Total water used including rainfall was 1479 and 1420 mm under direct seeding and conventional method.

Table 9: Average paddy yield and water productivity for rice crop under different RCTs at Kala Shah Kaku during 2008 and 2009

Treatment	Paddy Yield (Ton/ha)	Total water Application (mm)	Water Productivity (kg/m^3)
Double Zero Tillage	3.81	1049	0.36
Direct Seeding	3.93	1115	0.35
Bed-Furrow	3.83	1256	0.31
Conventional	4.1	1392	0.29

Table 10: Water use under direct seeding and conventional transplantation at Muridke during 2009

Treatments	Irrigation water Applied (mm)	Rainfall (mm)	Total water Application (mm)
Direct Seeding	1197	282	1479
Conventional	1138	282	1420

5.4 Paddy Yield and Water Productivity at Muridke

Basmati rice was grown during 2009 on farmer's field at Ratta Bher, Muridke. Size of experimental field was one acre each for direct seeding and conventional method. Crop conditions of rice crop under direct seeding and conventional methods are given in (Figure 4). Paddy yield and water productivity for rice crop is given at (Table 11). Paddy yield was recorded as 4.5 and 3.7 ton/ha under direct seeding and conventional method respectively. Paddy yield under direct seeding of rice was 22% higher as compared to conventional method.

Total water application that includes irrigation water and rainfall was recorded as 1479 and 1420 mm under direct seeding and conventional method of rice transplantation respectively. Water productivity of 0.30 and 0.26 kg/m^3 was found under direct seeding and conventional method respectively. Water productivity under direct seeding was 15% higher than conventional rice transplantation method.

Figure 4: Crop conditions of direct seeded rice at Muridke

Table 11: Paddy yield and water productivity for rice crop at Muridke during 2009

Treatment	Paddy Yield (Ton/ha)	Total water Application (mm)	Water Productivity (kg/m^3)
Direct Seeding	4.5	1479	0.3
Conventional	3.7	1420	0.26

6. Conclusions

Water productivity of rice-wheat system can be improved through adopting resource conservation tillage technology in the country in future. Generally farmers use more water for production of crops than the actual requirements. It is, therefore, imperative to adopt new crop establishment techniques which can enhance yield with limited available water. Salient conclusions drawn from the study are as follows:

- Crop water requirement of 600 mm was determined for rice crop.
- Water productivity was increased by 28% for Basmati rice through double zero tillage as compared to conventional method.
- Direct seeding resulted in an increase of 18% water productivity for Basmati rice as compared to conventional method.

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