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Research Article

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Improvement in Water Productivity without Yield Penalty of Direct Seeded Rice under Micro Irrigation Systems and Tillage Options in Indo- Gengetic Plain of India

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ABSTRACT

Declining water table in alarming rate is major challenge of sustainability of rice in South Asia. To address this challengea field experiment was conducted from kharif 2012 and 2013 on a loam soil to evaluate the performance of irrigation systems and tillage options.The substantial water saving 41 to 94 mm/ha in 2010 and 86 to 144 mm//ha in year 2011 was recorded with all the micro irrigation systems. The highest water productivity was recorded with sprinkler irrigation system than remaining irrigation techniques during both the study years. No yield penalty was recorded under micro irrigation systems. The performance of drip and sprinkler irrigation on yield contributing charter and yield was found at par with flood irrigation however, LEWA and Chapin technologies still need refinement for being applicable at field scale. In first year, grain yield of rice was better in reduced tillage however it was similar to zero tillage in second year of study. Overall results suggested that micro irrigation system especially drip and sprinkler has the potential to sustain rice yield with substantial water saving. But these micro irrigation systems and tillage methods needs to evaluate long term and over the wide range seasonal, site conditions and varieties.

Key words: *Kharif, Drip, Yield, Rice, Productivity, Irrigation Systems*

INTRODUCTION

The South Asia is facing key challenge of stagnating productivity growth, declining resource -use efficiency mainly diminishing availability of fresh water under the current production practices in the intensive irrigated rice-wheat system. It is a major concern for food security[3,15].

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Rice (*Oryza sativa* L) is used as a for 65% of India's population and contributes 20-25% of the agricultural GDP[18]. In India, rice is grown over an area of 43 million hectares with total production of 95 million tonnes amounting to 40% of the total food production (Fertilizer Statistics 2013-14). Among the conservation agriculture based practices of improving resource use efficiency i.e. energy, water and soil. Current main practice of puddled transplanting rice is required intensive use of all these three resources. Direct seeded rice (DSR) could be the option of saving of water and energy. Kumar and Ladha *et al*[11]., have reported that dry direct-seeding of rice and wheat without tillage or with zero tillage performed equivalent to conventional practice but with significant savings in water and labour use. Thus there is need to explore the possibilities of replacing the transplanting rice with direct- seeded rice.

Since the early 1970s, there has been a steady increase in the depth to the groundwater in most of the RW area of north-west India[1,4,5,6,7,13]. One of the main reasons of depletion is predominant use of flood (conventional) method of irrigation. Available estimates indicate that water use efficiency under flood method of irrigation is only about 35 to 40 percent because of huge conveyance and distribution losses[8,14].

The area expansion has mainly come through the expansion in irrigation facilities. Therefore, to produce more with the same amount of water or with less water, the water productivity must be increased through judicious use of irrigation water systems. One of the demand management strategies introduced relatively recently to control water consumption in Indian agriculture is micro irrigation, which includes mainly drip, sprinkler and LEWA (Low energy water application) irrigation methods. Under micro-irrigation, unlike flood method, water is applied desired interval and quantity using pipe network, emitters and nozzles. Therefore, the conveyance and distribution losses are reduced completely which result in higher water use efficiency under micro-irrigation. Though both drip and sprinkler irrigation methods are treated as micro-irrigation, there are distinct characteristic differences between the two in terms of flow rate, pressure requirement, wetted area and mobility[10]. However, the most of experiments were established on to evaluate the performance of direct seed rice. But very few work has been done on zero tillage and DSR especially the under micro irrigation system. Keeping the above facts in consideration a study was initiated in Indo gangetic plain of India with the objective to evaluate performance of direct seeded rice under reduced and zero tillage and assessments feasibility of the different micro irrigation system for improvement of water productivity.

MATERIALS AND METHODS

Experimental Site

A medium term study was conducted at Chirrori research farm of the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) during kharif 2010 and 2011, located in Indo-Gangetic plains of Western Uttar Pradesh, India (29^0 13' 96" N, 77^0 68' 43" E). The region enjoys semi-arid and subtropical climate with average rainfall 806 mm (75-80 % of which is received during June–September). Extremes of hot weather in summer and cold in winter season. Seasonal weather data including rainfall, evaporation rate, minimum and maximum temperature, during the two years are presented in Fig. 1. The site was under a continuous R–W system for many years before the establishment of the experimental farm. The initial soil characteristics from experimental site of upper layers were saline in nature, loam in texture, low in organic carbon & nitrogen and high in available phosphorus and potassium.

Experimental detail

The experiment was laid out in 3 replications in a split plot design with 5 treatments viz. T1 Farmer practice of water, T2: drip irrigation, T3: sprinkler irrigation, T4: Chapin (It was same as drip but cheap due to material used in chapin was low quality) , T5: Low energy water application (LEWA) in main plots and two tillage (zero and reduced) in sub plots. The sub-plot size was 50m x 20m.

Crop management

The site was cultivated and laser levelled two year prior establishment of the experiment. The reduced tillage plots were prepared by two harrowing and cultivators followed by wooden planking. However zero tillage plots were not disturbed. The rice crop was direct seeded on 19th June in 2010 and 15 June during 2011 with the short duration (115 days) hybrid variety Arize 6129 using a seed cum fertilizer drill. Seed rate was 25 kg/ha with row spacing of 20 cm.

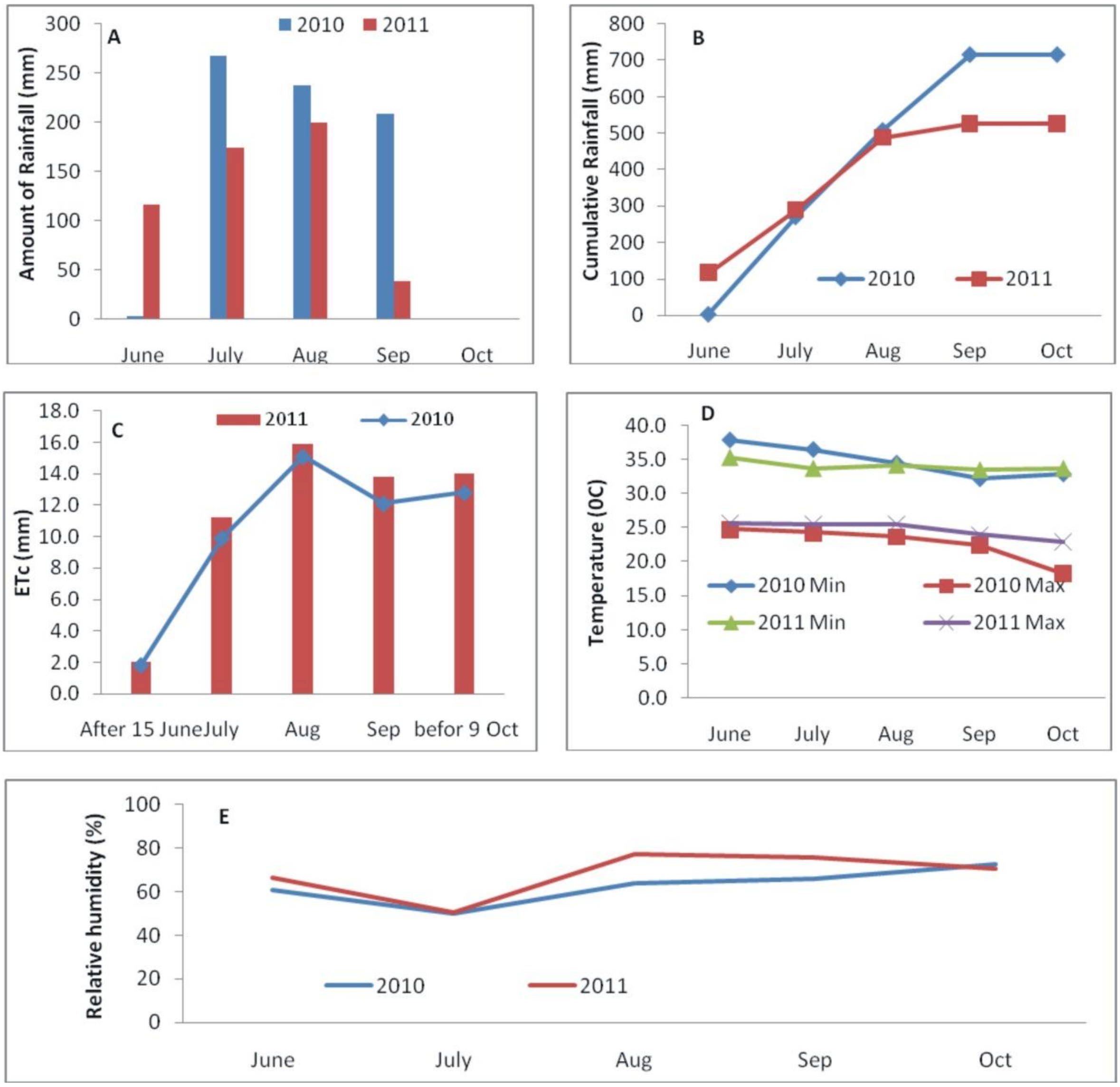

Fig. 1: Monthly rainfall (A), cumulative rainfall (B), monthly mean daily pan evaporation (C), monthly average daily maximum and minimum temperature (D), and monthly mean Relative humidity (E) during study years 2010and 2011.

Irrigation Schedule

The evapotranspiration (ET) based irrigation scheduling was prepared as per FAO recommendation for irrigation of rice crop. The amount of water required and time of water application by drip, and sprinkler is based on equation given below

$$E \times 0.7 \times Kc \times Kp \times A$$

Where, E is the open pan evaporation, 0.7 is a correction factor for converting pan evaporation to evopa-transpiration; Kc is crop coefficients; Kp is crop canopy factor and A is area.

Further amount of water application was determined assuming irrigation system efficiency drip (90 %) and sprinkler (70 %). Time of irrigation is based on discharge rate of different micro irrigation systems at a given pressure and amount of water application at particular stage. The water discharge rate of drip is 4 l/hr/drip and of sprinkler 140 l/hr/sprinkler. The minimum pressure required to run the system is 2.0 kg for sprinkler, 1.0 kg for each of drip. Drip and chapin plots were having 16 emitters per plots and drip emitter contains 125 dripper while chapin having 250 Whole in one emitter, whereas, sprinkler plots were having 36 sprinklers per plot.

Time of irrigation

Considering overall feasibility under the given conditions, the micro-irrigation systems (sprinkler, drip and chapin) were operated after lapse of 4 days. Wherever rainfall occurred and exceeded the crop evapotranspiration (ETc) requirement the irrigation was missed and next irrigation was given as and when soil moisture tension reached 20 kPa. The tensiometeres were installed in the individual plots for measuring soil moisture tension.

Flood irrigation:

Soil kept moist for the first 20 days to ensure complete germination. After that the irrigation was applied on the basis of tensiometer reading at 20 kPa (5 Cm depth of irrigation water). The micro irrigation system was installed by Jain irrigation system limited (JISL).

Fertilizer application

In DSR, Recommended dose of fertilizer 150 kg N/ha as urea and DAP, 32.3 kgP/ha as DAP and 62.5 kg K/ha as MOP and 5.25 kg Zn as ZnSO4.7H2O was applied. Basal dose of N and whole amount of P, K and Zn was applied at the time of sowing and after that nitrogen was top dressed in two splits at 20-25 DAS and 40-45 DAS, respectively. Apart from that three foliar sprays of 1 % ferrous sulphate were given for correcting iron deficiency.

Weed Management

Weed in zero-tillage plots before the seeding of rice was killed by spraying glyphosate at 900 g a.i. ha−1. In DSR, However after seeding of rice crop in all treatments weeds were controlled by applying a pre emergence herbicide (pendimethalin @ 1.0 kg a.i. $ha^{-1)}$1 day after sowing (DAS). Further, post emergence herbicide (bispyribac @ 20 g a.i. ha^{-1}) was applied in all the plots at 20 DAS. Weed that escapes from these treatments were removed manually at 45 DAS.

Pest management

Monocrotophos (400 ml per acre) was applied for controlling stem borer at 25 DAS and Gandhi bug at 70 DAS. Bacterial blight was controlled by the application streptocyclin along with copper oxi- chloride (6 g + 250 g per acre) at 30-35DAS in rice.

Observations

Water Management:

Separate water meter for each treatments were installed for measuring amount of irrigation water. Water productivity was computed as the ratio of grain yield to the total water use (irrigation + rainfall).The rainfall data was recorded using rain gauge. Soil water tension (KPa) was monitored daily by tensiometer installed permanently at 15 cm depth in without residue plots.

Yield and Yield Parameters Measurements

At maturity, crop growth and yield parameters that is, plant height, total number of effective panicles, panicle length, number of filled and unfilled grains panicle–1, sterility percentage and 1000-grain weight were measured. Total number of panicles was recorded using 1 m^2 quadrate at two places in each plot. Simultaneously 10 plants were randomly selected from each quadrate for measurements of yield parameters. Crop was harvested manually at 15 cm above ground level. Grain and straw yields were determined from an area of 5 by 5 m (25 m^2). The rice grains were threshed manually and wheat grains were threshed using a plot thresher; dried in a batch grain dryer, and weighed. Grain moisture was determined immediately after weighing. Grain yields of rice reported at 140 g kg−1 water content, respectively. Straw weight was determined after oven-drying at 70°C to constant weight and expressed on an oven dry-weight basis.

Statistical Analysis

All data were analysed by analysis of variance (ANOVA) using SAS 2009. The comparison of treatment means was made by the least significant difference (LSD) at 5% level of probability (p = 0.05).

RESULTS AND DISCUSSION

Weather

Total rainfall was 36 % higher in 2010 (716.9mm) than in 2011 (527.1mm) (Fig. 1); most of the 2010 rainfall was received in July, August and September whereas rainfall distribution of the 2011 was better but received in month of June, July, August. In year 2011, June month received higher amount of rain and coincide with the germination of direct seeded crop. The pan evaporation was also slightly higher in 2011which may be due to more solar radiation and less rainfall in 2011. Mean monthly minimum and maximum temperature was also lower in 2010 than 2011.

Water applied under different irrigation systems

The data pertaining in the table 1 revealed that water application by micro irrigation system was low as compared to flood irrigation system. The substantial water saving varied from 41 to 94 ha-mm in year 2010 and 86- 144 ha-mm during 2011, respectively as compared to flood irrigation. Drip irrigation saved 42 % & 48 % in year 2010 and 2011, respectively. (Table)

Water productivity

During both the study years, the significantly highest water productivity was recorded with sprinkler irrigation system (6.17 and 6.89 kg grain/mm water) followed by drip irrigation system (6.09 and 6.71 kg grain/mm water) which was significantly higher than flood irrigation (5.32 and 5.68 kg grain/mm water), Chapin (6.08 and 6.5 kg grain/mm water) and LEWA (5.59 and 6.46 kg grain/mm water), respectively. The indigenous system of LEWA was also significantly higher water productivity than flood irrigation system. The consumption of water for producing one kg grain was quite lower with all micro irrigation systems as compared to flood irrigation. Water consumption was higher in year 2010 than 2011 might be due to higher rainfall in year 2010 which increased production of direct seeded of rice. The saving of water by micro irrigation techniques especially drip and sprinkler is obvious because only evapotranspirated water was applied to root zone of crop with minimum loss of water. More over uniform distribution of water and maintained the moisture throughout the crop growing period. Low water productivity in LEWA and chapin in comparison to drip and sprinkler might be due to use of poor quality material caused higher loss of water, which indicates requirement of refinement in LEWA and chapin.

Yield attributes:

The data presented in table 3 revealed that significant effect of irrigation system, tillage methods and its interaction on yield attributing charteristitics except 100 grain weight. A consistent trend was observed in both the years. In year 2010 yield attributing characters were slightly better than 2011. A clear trend was observed with irrigation techniques and tillage practices. Panicle density of DSR was highest and statistically superior in sprinkler under reduced tillage condition in year 2010 and it was statistically similar only with drip irrigation in year 2011 as compared to remaining treatments. While panicle length was higher in sprinkler, chapin & drip in year 2010 and 2011 with reduced tillage than other treatment except sprinkler with zero tillage during both the year and chapin with zero tillage in only 2010. Similarly In case of filled grain/ panicle sprinkler with reduced tillage was significantly higher than other treatments. It was 199,215,210 and 204 higher than flood, drip, chapin & LEWA , respectively higher in reduced tillage and 197,207,200 and 200 higher than flood, drip, chapin & LEWA, respectively higher in zero tillage. However, after sprinkler and drip were performed better than other treatments. Similar trend was observed in 2011.The mean effect of reduced tillage was good as compared to zero tillage.

Yield

It is evident from the data presented in table 4 during both the study years the effect of treatments and its interaction was non-significant except tillage practices in year 2010. However, numerically higher grain yield was recorded with sprinkler followed by drip under reduced tillage condition during both the years. Only in year 2010 grain yield was significantly higher under reduced tillage than zero tillage, however in 2nd year the yield was statistically comparable in both the tillage practices. However total biomass and straw yield were exhibited statistically differences in between treatments. Effect of treatments on Straw and biomass yield was also found statistically comparable. However, Sprinker under reduced condition was produced numerically higher biomass and straw yield than any other treatments. The grain yield was slightly higher in 2010 than 2011 might be due to in 2011 higher amount of rain at the time of germination. It is also reported that due to uniform distribution of water micro irrigation system improved the rice grain yield significantly than flooded application. In contrast to research study in first year yield was higher in RT might be due to lower weed infestation in RT plots than ZT. However, weed dynamics was not made in present study. Although from second year our study results are in concurrence with the Liu and Kang[12], Yasser *et al*[20]., Gathala *et al*[2]., and Saharawat *et al*[15]. The improvement of yield attributes might be due to change in the micro-climate under different micro irrigation systems and ZT plot along with residue management that helps in moisture conservation, regulate soil temperature as compare to reduced tillage. Prevent puddling is known for improvement of physical properties in both RT and ZT[2,9,17,21], and in turn improves overall soil health, water-use efficiency, crop productivity, and farmers' income[16,19].

Table 1: Water applied and water saving in different micro irrigation techniques

Irrigation system	Irrigation Water applied (ha-mm)		Water saving			
			(ha-mm)		%	
	2010	2011	2010	2011	2010	2011
Flood	222	299	-	-	-	-
Drip	128	155	94	144	42	48
Capin	128	155	94	144	42	48
Sprinkler	158	197	64	102	29	34
LEWA	181	213	41	86	18	29

Table 2: Water productivity and water consumption by different irrigation techniques

Irrigation techniques	Water productivity (Kg grain mm^{-1} water)		Water consumption (liter kg^{-1} grain)	
	2010	2011	2010	2011
Flood	5.32	5.68	1881	1762
Drip	6.09	6.71	1643	1493
Chapin	6.08	6.5	1646	1539
Sprinkler	6.17	6.89	1622	1455
LEWA	5.59	6.46	1794	1549
SEm$\pm$	0.06	0.07	19.8	15.6
CD (P=0.05)	0.20	0.22	64.5	51.0
Tillage practices				
Zero tillage	5.6	6.23	1797	1613
Reduced tillage	6.1	6.67	1645	1506
SEm$\pm$	0.01	0.03	4.7	8.4
CD (P=0.05)	0.04	0.09	14.6	25.8

Table 3: Effect of different irrigation techniques and tillage practices on yield attributes of direct seeded rice

Tillage	Irrigation System	Panicle density m^{-1}		Panicle Length		Filled grain/panicle		Grain wt	
		2010	2011	2010	2011	2010	2011	2010	2011
(T1)ZT	(I1)Flood	201	192	24	23	199	197	24	24
	(I2)Drip	200	193	25	24	215	207	24	24
	(I3)Chapin	197	192	26	24	210	200	24	24
	(I4)Sprinkler	201	199	26	25	225	210	24	25
	(I5)LEWA	197	188	24	24	204	200	24	24
(T2)RT	(I1)Flood	208	195	24	24	206	204	24	24
	(I2)Drip	211	204	26	25	227	218	24	24
	(I3)Chapin	214	199	26	25	211	209	24	25
	(I4)Sprinkler	218	203	26	25	233	219	25	25
	(I5)LEWA	203	195	24	25	208	206	24	24
Mean of T	ZT	198.9	192.5	24.8	24.0	210.7	203.0	24.1	24.1
	RT	210.7	199.3	25.3	24.6	217.1	211.2	24.3	24.5
Mean of IS	Flood	204.1	193.5	23.8	23.4	202.7	200.7	24.0	24.0
	LEWA	205.6	198.5	25.3	24.5	221.3	212.5	24.3	24.4
	Chapin	205.3	195.3	25.8	24.4	210.5	204.7	24.1	24.6
	Sprinkler	209.5	201.0	26.1	24.9	229.3	214.5	24.4	24.8
	Drip	199.6	191.2	24.2	24.2	205.7	203.2	24.1	24.0
LSD 0.05									
T		1.6	2.3	0.5	0.5	1.2	2.9	NS	NS
IS		2.5	3.6	0.7	0.8	1.9	4.6	NS	NS
IS X T		3.5	1.4	1.0	1.1	2.7	6.5		

Table 4: Effect of different irrigation techniques and tillage practices on yield of direct seeded rice

Tillage	Irrigation System	Rice Yield (t ha^{-1})					
		Grain Yield		Straw Yield		Biological Yield	
		2010	2011	2010	2011	2010	2011
ZT	Flood	4.63	4.56	7.20	6.53	11.83	11.09
	Drip	4.78	4.43	7.38	6.79	12.16	11.22
	Chapin	5.06	4.50	7.08	6.68	12.14	11.18
	Sprinkler	5.16	4.56	7.35	6.83	12.51	11.39
	LEWA	4.91	4.63	7.43	6.75	12.34	11.38
RT	Flood	5.36	4.83	7.95	7.04	13.31	11.86
	Drip	5.50	4.82	7.98	6.93	13.47	11.75
	Chapin	5.24	4.69	7.75	6.78	12.98	11.48
	Sprinkler	5.54	5.02	8.50	7.36	14.04	12.38
	LEWA	5.12	4.94	7.83	6.97	12.95	11.90
Mean of T	ZT	4.9	4.5	7.3	6.7	12.2	11.3
	RT	5.4	4.9	8.0	7.0	13.4	11.9
Mean of IS	Flood	5.0	4.7	7.6	6.8	12.6	11.5
	LEWA	5.1	4.6	7.7	6.9	12.8	11.5
	Chapin	5.1	4.6	7.4	6.7	12.6	11.3
	Sprinkler	5.3	4.8	7.9	7.1	13.3	11.9
	Drip	5.0	4.8	7.6	6.9	12.6	11.6
LSD 0.05							
T		0.4	NS	NS	NS	NS	NS
IS		NS	NS	NS	NS	NS	NS
IS X T		NS	NS	NS	NS	NS	NS

CONCLUSION

The present study revealed that potential of micro irrigation systems in direct seeded rice. Substantial water saving was observed with micro irrigation systems particularly sprinkler and drip without any yield penalty of rice. The highest water productivity was recorded with sprinkler (6.17 & 6.89 kg grain /mm water) followed by drip (6.09 & 6.71 kg grain/mm water) which was significantly higher than flood irrigation (5.32 & 5.68 kg grain/mm water) during 2010 & 2011, respectively. The yield attributes and yield in zero tillage were similar to reduced tillages. Only first year yield was lower than reduced tillage, however, in second season grain yield was similar to reduced tillage. Therefore, zero tillage with residue retention and micro irrigation techniques especially either with sprinkler or drip may be potential of adoption in rice of Indo gangetic plain of India. However, the LEWA and chapin system still need much refinement for being applicable at the field scale.

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