MICRO IRRIGATION INFRASTRUCTURE ON CANAL COMMANDS FOR SUSTAINABLE RICE AND WATER PRODUCTIVITY UNDER DECLINING WATER AVAILABILITY IN NORTH-WESTERN PLAINS OF INDIA

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ABSTRACT

Rice is a predominant crop of north-western plains of India contributing substantially to the country's agricultural growth and food security. Rice cultivation requires extensive irrigation, which implies dependence on large quantities of canal & ground water. The Rice crop consumes 3000-5000 liters of water to produce one-kilogram rice, causing decline in ground water table 40-50cm per annum as conventional methods of water conveyance and application are highly inefficient. The quality of ground water is also not suitable for irrigation in most of the parts of North Western plains, so farmers largely depend on canal water which is also not available at tail end in the dark zones of the region. To overcome the water crises and to improve rice productivity, the existing irrigation infrastructure of open channels at field level has been converted into solar/grid connected pressurized pipe irrigation system in the canal commands, readily available for installing Micro Irrigation Systems. To motivate the farmers towards Micro Irrigation Systems in Rice crop an on-farm trial was initiated for two years with three planting methods i.e. manual and mechanical transplanting in puddled soil and direct dry seeding of rice (DSR) with three irrigation practices of flood, drip and sprinkler. Preliminary results revealed that drip irrigation potentially saved 56% and sprinkler irrigation 50% water in comparison of flood irrigation. The analysis of results indicates that pressurized irrigation is a viable option for higher rice and water productivity in canal commands.

Keywords: Rice, Micro irrigation system, Water Use, Yield, Solar/Grid, Canal Command.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most significant food crops in the world which is largely grown in Eastern and Southern Asia. It is grown in a wide range of environments and productive in many situations where other crops would fail. Rice-growing environments are based on their hydrological characteristics which include irrigated, rain fed lowland, upland. Water - nature's gift to mankind is not unlimited and free forever. The amount of water present in the universe is only about 1520 million cubic kilometers, 97% is ocean and sea water, 2% is frozen arctic waters and only 1% is water in lakes, rivers and underground water, which is portable water for direct use to humans (Shaker, 2004). Rice is an obvious target for water conservation as it is grown on more than 30% of irrigated land and accounts for 50% of irrigation water.

Worldwide, about 80 million hectare of irrigated lowland rice provides 75% of the world's rice production. The north-west Indo-Gangetic Plains (IGP) of India produces rice and wheat providing food security to India. Farmers in many rice-growing areas are likely to have only limited availability of irrigation water and, in future, it is predicted

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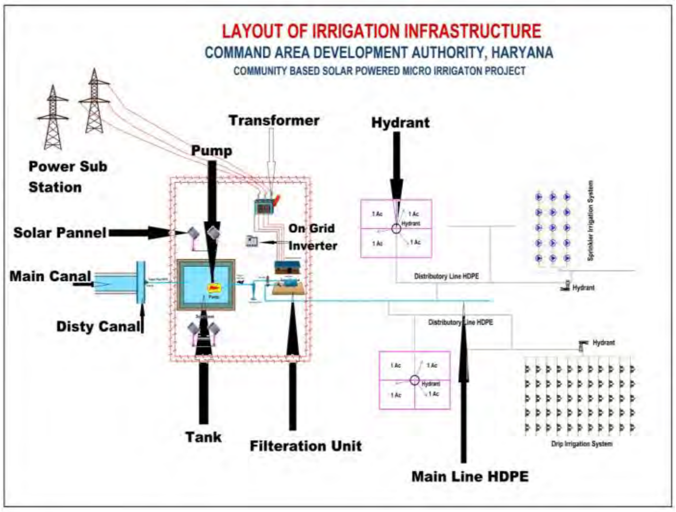
that in Asia, 17 million ha of irrigated rice areas may experience ‘‘physical water scarcity’’ and 22 million ha may have ‘‘economic water scarcity’’ by 2025 (Bouman and Tuong, 2001). Thus, water scarcity threatens the sustainability of irrigated rice ecosystems since it may no longer be feasible for farmers to undertake wet cultivation and flood fields to ensure good crop establishment and control weeds (Johnson and Mortimer, 2005). For example, Jeevandas et al. (2008) estimated a groundwater depletion rate of 77cm per year in the Amritsar district of Punjab (India). Such an alarming rate of ground water decline is forcing researchers and farmers to consider approaches for increasing the water productivity of rice. Furthermore, unavailability of irrigation is a major cause of yield reduction especially for the late cropping season from July to October in North-Western plains of India.

About 80% of the agriculture land of the Haryana state situated in different canal commands including the lift canal commands, but the actual average annual intensity of canal irrigation in the State is only about 70% (combined for both the crops of Rabi & Kharif) which undoubtedly reveals the limited availability of canal water (Neeraj *et al*., 2018). Large dependence of the State’s agricultural sector on the ground water has led to overexploitation of this source of water and consequently the water table has registered a steep decline in the fresh water belts and rise in saline ground water areas leading to the problems of water logging and soil salinity. The major source of irrigation is canal commands in the region with good canal network, but have substantial losses up to 50% in conveyance up to fields resulting in 38 to 40% water use efficiency for canal and about 60% for ground water irrigation schemes. The quality of ground water is also not suitable for irrigation so farmers depend mostly on canal water which is not available at the tail end of canal of the dark zones of the region. Therefore, efficient irrigation system is necessary for bumper harvest of rice as well as to realize optimum benefits with mitigation of consequential side effects like water logging in canal head and no water in the tail end of the canal. In some parts of the world, sprinkler irrigation facilities are in use but this also amounts to water wastage. To overcome this, Haryana took rehabilitation of the on-farm field channels by launching a pilot project for increasing carrying capacity through the pressurized irrigation system. In this, Solar/Grid Powered Micro Irrigation Infrastructure has been installed in the Canal Commands by providing community-based water storage tank near outlet head, Pumping Unit (Grid/Solar Powered), Filtration units, HDPE pipe network/Hydrant/Outlet assembly, Valves etc. as shown in layout plan Figure 1. Drip/Sprinkler irrigation sets will be installed by the individual farmers in their farm holdings by availing the benefits of subsidy. It is proposed to take water from canal outlet through underground pipeline with gravity and to store the same in the tank of appropriate size for construction of which the land shall be made available by the WUA of the shareholders of the canal outlet. Solar/Grid powered pumping system connected through net metering has been installed nearby the tank with proper filtration systems to avoid any chocking. Water has been carried to entire area of the chak of the outlet through HDPE pipe line network under pressure. The entire pipe network has been buried under ground at 3 feet deep to avoid land acquisition. Water with the requisite pressure for running of the drip/sprinkler set has been made available to each shareholder at his farm holding through the common infrastructure to be operated & maintained by the Water User’s Associations.

Drip irrigation is a more convenient choice of irrigation system as it could provide for rice growth with water and the nutrients dissolved in the water in a relatively flexible way. It is possible to establish drip irrigation *in-situ* as long as there is water source from a well dug out from underground or from a river nearby. Drip irrigation is considered as an alternative irrigation approach for better water and fertilizer usage efficiency (Assouline, 2002; Hanson & May, 2003; Eid et al., 2013). Drip irrigation can supply water both precisely and uniformly at a high irrigation frequency compared to furrow and sprinkler irrigation, thus potentially increasing yield, reducing subsurface drainage, providing better salinity control and better disease management since only the soil is wetted whereas the leaf surface stays dry (Hanson & May, 2007). However, there are still many things unclear about the practicability of this irrigation system as to the water use efficiency on rice plant, the yield ability, impact on environment and the production cost. Thus, this project is carried out in the canal commands of north western plains of India aimed at exploring the possibility of growing more and environment-friendly rice with less water through joint application of water-saving and pressurized irrigation system with different planting methods.



(Adopted from Neeraj *et al*., 2018)

Figure 1. Layout of irrigation infrastructure adopted in command area of Haryana

2. METHODS

The aim of this research is to study the rice yield using optimum water by reducing conveyance loss in canal command regions of North-Western plains of India. Experimental studies were carried out during kharif season in 2017 and 2018 in the fields at Kurukshetra region of Haryana state in India. The experimental site is situated at Latitude 30˚75’N and Longitude 76˚78’E at an altitude of 260 m above mean sea level (MSL). The Soil type of the experimental field is clay loam. Monsoon starts at the end of June and extends up to September. The annual rainfall of the region is 720mm. During the cropping period, total rainfall of the study area was 337 and 211mm in 2017 and 2018, respectively (Fig. 2).

The field experiment was conducted using PR 114 variety of rice. In this study, three different irrigation systems (drip, sprinkler and traditional flood) and three planting methods (Direct seeding rice, Mechanical transplanting and Manual transplanting) were used. The irrigation treatments were based on average water requirement of rice according to soil moisture condition. The irrigation was given through HDPE pipe by 12.5 HP motor from the common infrastructure. The pressure maintained in the system was 2.5 kg/cm^2. From the sub-mains, in-line laterals of 16 mm were laid at a spacing of 0.6 m with 2.4 lph discharge with emitters placed at a distance of 40 cm. A line source of sprinkler irrigation system was used for sprinkler irrigation. The sprinkler heads were located at 10 m intervals on the lateral pipe and total numbers of sprinklers were 40 with part cycle for one-acre land area. The flood irrigation was maintained at 5.0 cm water depth in traditional method.

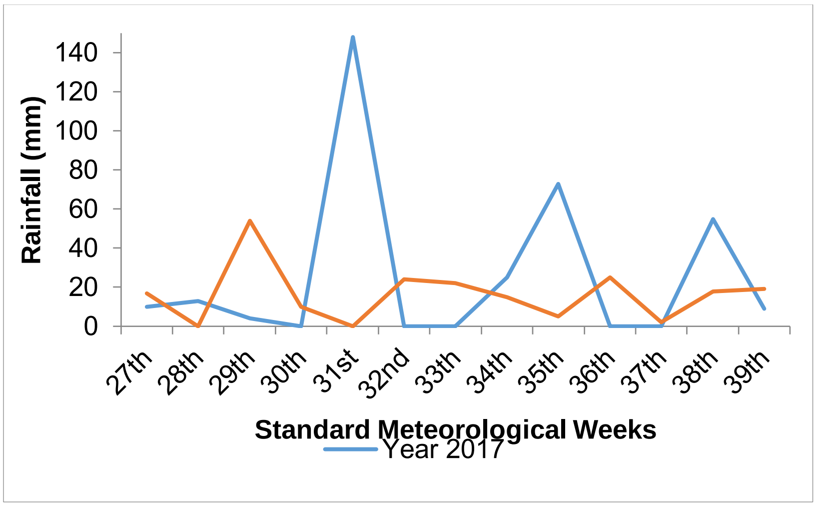


Figure 2. Rainfall during the experimental period in the year 2017 and 2018

The urea as nitrogen and muriate of potash (MOP) as source of fertilizers were applied through fertigation under drip and sprinkler systems whereas Single Super Phosphate (SSP) and Zinc fertilizers were applied through soil application during the sowing time. In flood irrigation method, all fertilizers were applied by broadcasting, in which, half dose of N, full dose of P and K fertilizers were applied through basal application and remaining half dose of N fertilizers applied through top dressing. Pre-emergence herbicides of Pretilachlor and pendimethalin at 1.25 kg per hectare were applied in transplanted rice of mechanical and manual methods and direct seeded rice, respectively. During the study period, data on water used for irrigation including control (flood irrigated, puddled) plus monsoon rains received during the crop duration per hectare yield in kg/ha, water productivity in kg grain per m3, water used for irrigation calculated for each irrigation and planting systems. The total expenditure incurred on inputs such as seeds, manure, fertilizers, chemicals, pest's management, weeds control, labour used for various operations from land preparation to final harvest, cleaning etc. and irrigation system costs were recorded and the savings in water and expenditure over control calculated. The recorded data were subjected to statistical analysis in the two-factor factorial analysis using WASP Package (Version 2.0) following the method of Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1 Water Use Studies and Their Efficiency

Total water used was highest in flood irrigation method (209.43 ha-cm) when compared to drip irrigation (91.40 ha-cm) and sprinkler irrigation (103.27 ha-cm) methods (Table 1). According to planting methods, DSR transplanting used higher water requirement (146.23 ha-cm) followed by mechanical (132.67 ha-cm). The lower water use was observed in manual transplanting method (89.20 ha-cm). Drip and sprinkler irrigation systems in manual transplanting method used less water 84.0 ha-cm and 89.2 ha-cm, respectively. Further the results show that drip irrigation saved 56.18% of total water required as compared to flood irrigation method. Similar result was also reported by Rajeev *et al.*, 2018 that water saving by 30.7 and 28.7 per cent in drip and sprinkler, respectively than flood irrigation under rice ecosystem. In an another study reported by Bhardwaj *et al.*, 2018 that drip irrigation in rice saved about 51 per cent irrigation water over conventional flood irrigation method. In case of total water used to produce a unit of rice grain yield, farmers' method used more water (Figure 3). In comparison with planting and irrigation methods, flood irrigation method consumed higher rate in all the planting methods particularly in mechanical transplanted rice. In contrast, water used per unit of rice grain produced was lower in drip irrigation under all the planting methods. Higher yield with less water was recorded to produce a unit of rice grain yield (1259 l kg^{-1}) in manual followed by drip in DSR (1464 l kg^{-1}). The less use of water in drip irrigation system over flood irrigation was mainly due to the controlled water release near the crop root zone (Punamhoro *et al*., 2003). Higher yields are due to higher intake of nutrients by crop due to timely and frequent supplementation of water and nutrient to root zone leading to decrease in leaching and volatilization losses of nitrogen. The favourable effect of water and nutrients on crop growth and grain yield in drip irrigation probably resulted in higher efficiency of water use. These results are in accordance with findings of Vijayakumar (2009) and Sundarapandian (2012).

3.2 Rice Yield

Data presented in Table 2 illustrate that among the different irrigation methods the highest grain yield was recorded with drip irrigation (6281 kg ha^{-1}) which was slightly more than sprinkler irrigation (6057 kg ha^{-1}) method. In case of planting methods, rice transplanted manually recorded highest grain yield (6402 kg ha^{-1}). Mechanical transplanted rice was observed to have lower rice grain yield (5466 kg ha^{-1}). These results indicated that rice yield in drip irrigation increased by 11% over flood irrigation method. Sprinkler irrigation increased yield by 7.37% over flood irrigation.

Table 1. Various irrigation practices influence on total water use under different planting methods

	Total water used for one ha (litre)				Water used (ha-cm)				% of water saved in comparison to flood irrigation method			
	Flood	Drip	Sprinkler	Mean	Flood	Drip	Sprinkler	Mean	Flood	Drip	Sprinkler	Mean
DSR	23057709	9460927	11345846	**14621494**	230.60	94.60	113.50	**146.23**	-	58.97	50.79	**54.88**
Mechanical	19532570	9557579	10714289	**13268146**	195.30	95.60	107.10	**132.67**	-	51.07	45.15	**48.11**
Manual	20239494	8396995	8924308	**12520266**	202.40	84.00	89.20	**125.20**	-	58.51	55.91	**57.21**
Mean	**20943258**	**9138500**	**10328148**	**13469969**	**209.43**	**91.40**	**103.27**	**134.70**	**-**	**56.18**	**50.62**	**53.40**
Farmers method	27466400				274.66							
CD(A) (p=0.05)	*380508*				*4.10*							
CD(A) (p=0.05)	*3850508*				*4.10*							
CD(A×B) (p=0.05)	*659059*				*7.11*							

The authors recorded considerable increase in yield under drip irrigation as compared to flood or sprinkler irrigation. Higher grain yield with drip may be due to its superiority in producing higher productive tillers, panicle length, thousand seed weight and total number of filled grains panicle with lower percentage chaffyness than the other treatment. High numbers of productive tillers were due to continuous availability of water and nutrients resulted in higher production of dry matter under drip irrigation. In contrast, lower yield resulted for DSR method was due to paddy seed sown in the period of hot summer (late May month) causes poor germination consequently sparse plant population. Contradictory, Bhardwaj *et al*., 2018 reported higher yield associated with DSR in drip irrigation system. Similarly, Thangjam *et al.,* 2018 reported rice grain yield of drip irrigation in DSR was increased up to 35.31% over conventional transplanted rice. Overall reduction of rice yield in mechanical transplanted rice could be due to improper planting done in the plots caused lower seedling rates per unit area. These findings are in conformity with the findings of Gururaj (2013) and Soman (2012).

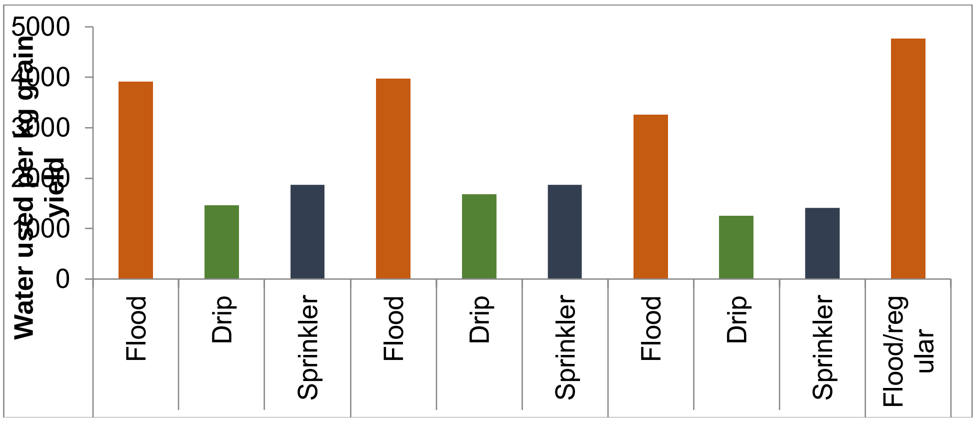


Figure 3. amount of water used to produced one kg grain yield of rice under different irrigation and planting methods (Two year pooled mean data)

3.3 Economics

The economics of different treatments in planting methods under both micro irrigation and conventional method of irrigation were worked out and are presented in Table 3. The micro irrigation system has been found more profitable than surface irrigation due to higher yield. Among the different irrigation methods the gross returns were higher when the crop was irrigated with drip system (Rs. 109920 ha^{-1}) these were closely followed by the treatment with sprinkler. This is mainly due to increase in grain yield as compared to rest of the treatments. On the other hand, among the different planting methods, manual transplanted rice was found to be higher gross return (Rs. 112034 ha^{-1}). The lower gross return was observed in mechanical transplanted rice.

Table 2 Various irrigation practices influence rice grain yield under different transplanting method (two-year pooled mean data)

	Yield (kg/ha)				**Increase in yield (kg/ha)**				**% of increased yield in comparison to flood irrigation method**			
	Flood	**Drip**	**Sprinkler**	**Mean**	**Flood**	**Drip**	**Sprinkler**	**Mean**	**Flood**	**Drip**	**Sprinkler**	**Mean**
DSR	5894	6464	6080	**6146**	-	570	186	**378**	-	9.67	3.16	**6.42**
Mechanical	4920	5706	5773	**5466**	-	786	852	**819**	-	15.97	17.34	**16.66**
Manual	6216	6673	6317	**6402**	-	458	101	**279**	-	7.35	1.62	**4.49**
Mean	**5677**	**6281**	**6057**	**6005**	**-**	**604**	**380**	**492**	**-**	**11.00**	**7.37**	**9.19**
Farmers method	5759											
CD(A) (p=0.05)	176.6											
CD(A) (p=0.05)	176.6											
CD(A×B) (p=0.05)	305.9											

At the same time, higher net returns (Rs.70956 ha^{-1}) were recorded in rice grown under drip irrigation system comparing to sprinkler (Rs.68577 ha^{-1}) and flood irrigation (Rs. 62878 ha^{-1}) methods. Similarly, transplanted manual method (Rs. 73431 ha^{-1}) recorded higher net return than other methods. A combination of drip irrigation and manual transplanted rice has comparatively given higher net return (Rs. 76829 ha^{-1}) and the lower return was observed with flood irrigation in mechanical transplanted rice (Rs. 54827 ha^{-1}). Andrianaivo (2002) reported that optimal water use can enhance returns from micro irrigation with enhanced labour productivity and far higher net income than traditional methods for the cultivation of rice. The findings of the present study are consistent with Andrianaivo's analysis and that of many other studies. These results were in accordance with the findings of Veeraputhiran *et al*. (2002), Abdelraouf *et al*. (2013) and Richakhanna (2013).

Table 3. Economics and monetary benefits by adopting various irrigation methods under different transplanting

	Cost of cultivation (Rs/ha)				Gross income (Rs/ha)				Net income (Rs/ha)			
	Flood	Drip	Sprinkler	Mean	Flood	Drip	Sprinkler	Mean	Flood	Drip	Sprinkler	Mean
DSR	40659	43159	41609	41809	103143	113120	106404	107556	62484	69961	64795	65747
Mechanical	31278	33778	32228	32428	86105	99857	101026	95663	54827	66079	68798	63235
Manual	37453	39953	38403	38603	108777	116782	110542	112034	71324	76829	72139	73431
Mean	36463	38963	37413	37613	99342	109920	105991	105084	62878	70956	68577	67471
Farmers method	37453				100788				63335			

4. CONCLUSION

The present study found that the adoption of drip irrigation combined with manual transplanted rice offers substantial agronomic and economic advantages for rice growing farmers on canal command regions of North-Western India. Plant growth and grain yield were found significantly higher in drip-irrigated plots. Apart from high yield, water productivity and water use to produce rice grain yield are far better in drip-irrigated rice cultivation than with manual transplanted. The evidence assembled and analyzed here suggests that manual transplanted rice with drip irrigation is a promising adaptation for reducing the water and energy demand of rice crop in the canal command area of North-Western parts of India. However, long-term, multi-location trials will be needed to arrive at percentages of water and cost saving that is achievable under varied and specific conditions.

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