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Spread of Drip Irrigation and Fertigation in India and its Role in Enhancing Water Productivity of Rice Crop

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Abstract

Micro irrigation is found to be the only alternative to sustain irrigated crops in a scenario of impending shortage of fresh water the country is facing. Farmers in India have successfully adopted MI taking the country to number one position in MI coverage (16.6 million ha) in the world. Continuing with the adoption process, even rice crop is successfully grown with drip irrigation. Data on yield, water consumption and water productivity of basmati rice grown in selected farmers' field with drip irrigation in Haryana is reported here. Rice yield improved by 10-18%, water consumption reduced by 51% and water productivity enhanced by 63%. The drip system could also be adapted to the rotation crop in the rice-wheat cropping system.

Key words: Drip irrigation, fertigation, rice, water productivity.

Introduction

Agriculture in India is climate restricted; 48% of the geographical area of the country receiving less than 1000 mm rain and the rest 1000-2500 mm. The difficulty is that the rainfall is occurring in 3-4 months' duration making it imperative for rainwater storage and irrigation. But the available water for irrigation is not enough to cover the net cultivated area. Only 42 % of cultivated area is presently irrigated. Irrigation cover cannot be increased as the available 1143 BCM water would be insufficient. By 2050 our water need (both irrigation and total need) would cross the availability level. This is a grim situation. It is made more so by the need for increasing food production. To achieve the increased food production of 494 million t by 2050, our net irrigated area should increase from 62 million ha to 146 million ha. This cannot happen as water is limited. Production cannot be increased by increasing in area alone; area will increase only by 2 million ha during 2010-2050. So we are into a very difficult situation.

Micro irrigation in India

The only way out is to identify water conserving irrigation methods. Incidentally, the technology of micro irrigation serves better in this scenario. It offers a way of irrigating more land with less water (water security); more yield with less water (food security) and more food production with less energy use (energy security).

Today, micro irrigation technology has become very popular in India and been adopted in large areas in several states of the country. This stage has come about over a period of past 30 years. The role of private manufacturers, government policies and level of farmer awareness and the assistance of media etc. have helped to arrive at the present situation.

The coverage of micro irrigation (MI) is 16.6 million ha (drip + sprinkler) in India (Table 1) (2022 March end, PMKSY, GoI). The awareness level however has grown tremendously. The spread of technology has however, been restricted to states like, Andhra Pradesh, Gujarat, Karnataka, Rajasthan, Tamil Nadu, and Madhya Pradesh, the so called TOP 7 of India (Table 1). The government subsidising the system cost first began in Maharashtra (at State level), and later spread to other states. Top 7 states' administration implemented the Central (Federal) government subsidy schemes with more ardour and commitment. Some of these states also toped up the subsidy amounts from their own resources. Few of these states like Andhra Pradesh (APMIP), Gujarat (GGRC) and Tamilnadu (TanHODA) have created special purpose administrative entities for extension and administration of MI provision in their states. These special purpose bodies and horticulture and/or agriculture departments in other states took over the effective administration of the introduction, spread and farmer level utility of MI systems in collaboration with the large MI suppliers who opted to work with the governments in these states. Farmers and other users of the MI systems are getting trained in the farm on the operation and effective use of the MI components. Most of these training and capacity building is initiated and jointly done by private supplier companies working hand in hand with the public extension bodies. Thus a silent revolution has been occurring in the remote farming villages of not only the in the TOP 7 but other states also. In the years to come, this era of rapid reach of MI in Indian farms would probably be designated as Golden Era of irrigated crop production. Among the TOP 7 states Andhra Pradesh, Karnataka, Maharashtra, Tamilnadu and Gujarat have covered more than 30% of their respective net irrigated area with MI.

Introduction of drip, both surface and sub- surface, to closely planted row crops (like sugarcane, cotton, cereals, pulses and oil seeds and flower crops and vegetables) in addition to tree crops has really caused a revolution in MI reach. Even States with sufficient water resources are adopting micro irrigation which is a good sign.

The idea of rain water harvesting, and farm pond concept would have to be taken with high priority to bring in the presently rain fed areas also under micro irrigation. According to the latest data from Min. Agri. GoI. (2021) Andhra Pradesh (1,68,613) Maharashtra (1,23,399) and Tamil nadu (57,114) followed by Rajasthan (30,482) are the leading states with most micro- level water harvesting/ storage structures. The micro storage structure in combination with micro irrigation offers possible sustainable means of increasing the irrigation cover. It is a heartening trend that this combo is getting acceptance. This strategy also leads to convert more rainfed land into irrigation.

Table 1 Current status of reach of micro irrigation in Indian States

Micro irrigation coverage in different states in India as on June 2022**						
TOP 7	**STATES**	**Drip (ha)**	**Sprinkler (ha)**	**Total Micro Irrigation (ha)**	**Share of Drip**	**Share of Sprinkler**
1	Andhra Pradesh	1716673	626915	2343588	0.73	0.27
2	Gujarat	1135403	999476	2134879	0.53	0.47
3	Karnataka	953297.7	1762250.14	2715547.9	0.35	0.65
4	Maharashtra	1572242	691906.41	2264148.1	0.69	0.31
5	Rajasthan	385044	1840484	2225528	0.17	0.83
6	Tamil Nadu	963714.8	448785.91	1412500.7	0.68	0.32
7	Madhya Pradesh	476572.3	334840.18	811412.48	0.59	0.41
	Sub total	7202946	6704657.64	13907604	0.52	0.48
North zone						
8	Haryana	47662.79	652795.84	700458.63	0.07	0.93
9	Himachal Pradesh	5160	4130	9290	0.56	0.44
10	Jammu & Kashmir	24	70.1	94.1	0.26	0.74
11	Punjab	36640.81	15359.19	52000	0.70	0.30
12	Uttar Pradesh	58837	270300	329137	0.18	0.82
13	Uttrakhand	18161.64	12644	30805.64	0.59	0.41
	Sub total	166486.2	955299.13	1121785.4	0.15	0.85
East zone						
14	Bihar	21370.62	113635.1	135005.72	0.16	0.84
15	Chhattisgarh	39257.6	368440.2	407697.8	0.10	0.90
16	Jharkhand	41159.45	17969.61	59129.06	0.70	0.30
17	Odisha	37495.02	166114.11	203609.13	0.18	0.82

Micro irrigation coverage in different states in India as on June 2022**						
TOP 7	STATES	Drip (ha)	Sprinkler (ha)	Total Micro Irrigation (ha)	Share of Drip	Share of Sprinkler
	Sub total	139282.7	666159.02	805441.71	0.17	0.83
West Bengal, Assam and North East						
18	Arunachal Pradesh	2841	781	3622	0.78	0.22
19	Assam	3767.8	10302	14069.8	0.27	0.73
20	Manipur	288	2924	3212	0.09	0.91
21	Meghalaya	308	307	615	0.50	0.50
22	Mizoram	3428.43	1428	4856.43	0.71	0.29
23	Nagaland	4895	6072	10967	0.45	0.55
24	Sikkim	6383	5617	12000	0.53	0.47
25	Tripura	2304	3204	5508	0.42	0.58
26	West Bengal	10649.11	109073.64	119722.75	0.09	0.91
	Sub total	34864.34	139708.64	174572.98	0.20	0.80
27	Goa	1186	1129	2315	0.51	0.49
28	Kerala	23274.89	8438.17	31713.06	0.73	0.27
29	Telangana	355825.2	140389.2	496214.4	0.72	0.28
30	Others	15169	30636	45805	0.33	0.67
	Sub total	395455.1	180592.37	576047.46	0.69	0.31
INDIA TOTAL		**7939035**	**8646416.8**	**16585452**	**0.48**	**0.52**

** Data sources: Compiled using the data reported in the following sources

1. Department of Agriculture, Cooperation & Farmers Welfare
   Pocket Book of Agricultural Statistics 2018- 19 (data up to 2019 March)
2. PMKSY, Ministry of Agriculture and Framers' Welfare Report June 2021
   (Data from 2019-2021)
3. Personal communication (2021 March to 2022 June) from PMSKY

Micro irrigation for rice and rice based cropping systems

India is the world's second largest producer of Rice. It is cultivated over an area of 44.2 million ha, which is about 50 % of the total irrigated agriculture area of the country (Anon, 2016). Short duration rice cultivation in rainy season (Kharif) is common in almost all States, however its cultivation is more concentrated in Northern States of Haryana and Punjab besides Eastern states and the Southern Peninsula.

Traditionally, low land rice or wet rice is cultivated in puddled soil as semi-aquatic crop. Under the low land system, water is consumed as much as 2295 mm/ha and 3000- 5000 liters utilized by the crop to produce one kg of grain [Dawe, 2005]. The water productivity is as low as 0.15 kg/m3 [Ghosh et al 2010]. The excessive use of irrigation water for rice production is a major socioeconomic, environmental and health concern for the region [Soman, 2012]. Several rice exporters' work in Haryana, for example, buying paddy from small holder farmers. The water footprint of these exports is extremely high and uncomfortable to afford.

Rice is also cultivated as dry land crop under rain-fed conditions in about 28 % area, by ploughing and harrowing the field dry and by direct sowing of the seeds. Such aerobic rice system, specially evolved rice varieties are cultivated as in Upland system with irrigation. The seeds sown directly (DSR) and the soil moisture maintained to field capacity throughout the period of crop growth. Compared with traditional low land rice system, water inputs in aerobic rice system were less, 470-650 mm) (Soman, 2012, Soman et al 2018).

Rice-Wheat system is a pre dominant cropping system of India. Haryana has Rice-Wheat cropping system as irrigated and rain-fed crops. Farmers still use the conventional practices of irrigation and method of cultivation of rice so that the water table in Haryana is declining at a rate of 30-50 cm per year. The water table in 1970 was around 5 meter which has become 38-40 meter at present because of decline. The water productivity of rice is said to be 400 g/m3. Keeping this in mind the Water Productivity Project, WAPRO has been launched in Haryana, in 2018 by the active contribution and participation and co-funding of the Swiss Agency for Development and Cooperation (SDC), Helvettas, and Jain Irrigation Systems Ltd., and Partners in Prosperity, an NGO. The data which form the basis of this paper is collected from this on farm project by Jain Irrigation scientists.

All the farmers have been irrigating the land through ground water extraction from bore wells. The farmers are using huge volumes of water for getting a good yield. Rice based cropping system is the predominant cropping system in the four districts. The average productivity of Coarse Rice is about 4-5 t/ha and for Basmati is around 2.5-3 t/ha. The average rainfall in Haryana during the monsoon is low (in sufficient for a full season rice crop). More than 75% of irrigation water has been ground water. A pre-project survey indicated that in spite of declining water table farmers are pumping water for irrigation without any restriction.

At Jain Irrigation, we have come up with a solution in 2007-2008. Irrigating rice crop with drip-fertigation technology reduces water consumption and methane emission besides increasing rice productivity. Soman, 2012 and Soman *et al.,* 2018 reported that aerobic rice hybrid ADT-45 and genotypes 27-P31,27-P63, PHB-71, ARIZE-6129, and ARIZE-6444 using drip irrigation with poly/paddy husk mulch, produced yields 4.5t-8.19 t/ha, harvested early by 8-10 days,17.7 to 25.2 % more yield than the conventional flooded cultivation system and in 27-P31, the maximum water productivity was 0.713 kg grain/m3 water. Anusha and Nagaraju 2015 compared rice genotypes under drip irrigation with conventional puddled and transplanted system and observed that across genotypes drip irrigated rice recorded significantly higher yield 7934 kg/ha, 19% higher than that of conventional flood system (6659 kg/ha), resulted in 58% water saving. Water productivity was highest under drip (11.80 Kg/ha mm) as compared to puddled and transplanted rice 4.17 kg/ha mm.

We continued our interventions with drip-fertigation in the Basmati growers' belt in Southern Haryana. This paper describes on-farm results of the work done in Haryana in farmers' fields as part of the project WAPRO. Under this project SDC funded a part cost of drip systems supplied to the farmers and Jain Irrigation, the technology provider, besides implementing the project and providing agronomy support to the farmers also provided part finance for the drip systems. The project farmers are all Basmati growers from Kaithal, Kurukshetra and Ambala districts of Haryana. Jain team has identified some 19 farmers in these districts who agreed to take up drip irrigated rice cultivation. The farms could be installed with drip during the planting season, *Kharif* 2019.

Data on yield, rain fall, irrigation water, fertilizer use, and yield of these fields were monitored. Detailed data on yield components (yield, tiller number per hill, gran per panicle and grain weight) were also recorded. In this paper, however we stress on yield and water productivity only.

We had already standardized package of practices (POP) for drip irrigated rice cultivation after 12 years of experimental and demonstration trials in many parts of India in farmers' fields. (Soman et al 2018). Generally, the package consists of the following steps.

Table 2. Irrigation schedule for Drip method for rice in Kurukshetra, Haryana $

Period	Pan Evaporation mm/day	Water requirement of rice l/ac/day
June 15- June 30	5.3	1960
July 1- July 15	5.0	11890
July 16- July 31	4.3	12105
Aug 1 -Aug 15	4.7	17547
Aug 15 - Aug 31	4.5	16684
Sept 1 - Sept 15	4.7	14540
Sept 16 - Sept 30	4.4	13724
Oct 1- Oct 15	5.3	13118

Table 3. Fertigation schedule for rice adopted in the farmers' fields.

Recommended fertilizer 60:24:16 kg/acre NPK. Basal dose of 50 kg/acre NPK (12:32:16) applied direct to soil at planting. Balance fertilizer is fertigated as per the schedule given below.

Growth Stage	Days after Sowing	Duration	Schedule
Vegetative	20-59 DAP	39 days	2.1 kg UREA per day or 14.7 kg /week
			1 kg MKP per week for 5 weeks
			2.5 kg MgSO4 per week for 4 weeks
			2 kg Zn EDTA per week for 5 weeks
Reproductive	60-89 DAP	29	5.1 kg UREA per week for 4 weeks
			1 kg MOP per week for 4 weeks
			1 kg Zn EDTA per week for 3 weeks (Last dose only 0.5 kg)
Grain Maturity	90-115 DAP	25	3 kg MOP per week for 3 weeks. (last dose only 1 kg)

Irrigation and fertigation were done as per schedules prepared for the rotation crop (wheat) after rice. Most of the farmers followed the Rice with a Wheat crop in the Rabi season on the drip system. Jain agronomist followed and monitored the rotation crops. The farmers were trained on the irrigation and fertigation schedules for the rotation crops.

Results and Discussion

Rice Yield

Under conventional flood yield ranged from 2.75 to 7.5 t/ha across different rice varieties; and under drip irrigation it ranged from 2.5 to 8.1 t/ha., The varietal difference in yield is very dominant and is expressed both under flood and drip methods of irrigation. The overall shift in yield because of drip irrigation hovered around 10-18%. Overall, transplanted rice yielded more both in flood and drip. Drip out-yielded in both DSR and TPR.

Irrigation water consumption of rice

Average irrigation water consumption in flooded fields is 6324.5 m^3/ac/season and in drip fields 3084 m^3/ac; Drip method releases an average 3240.5 m^3 water/ac for other uses (**Figure 1**). Average water consumption under TPR was more; TPR flood uses 6850 m^3/season and TPR drip

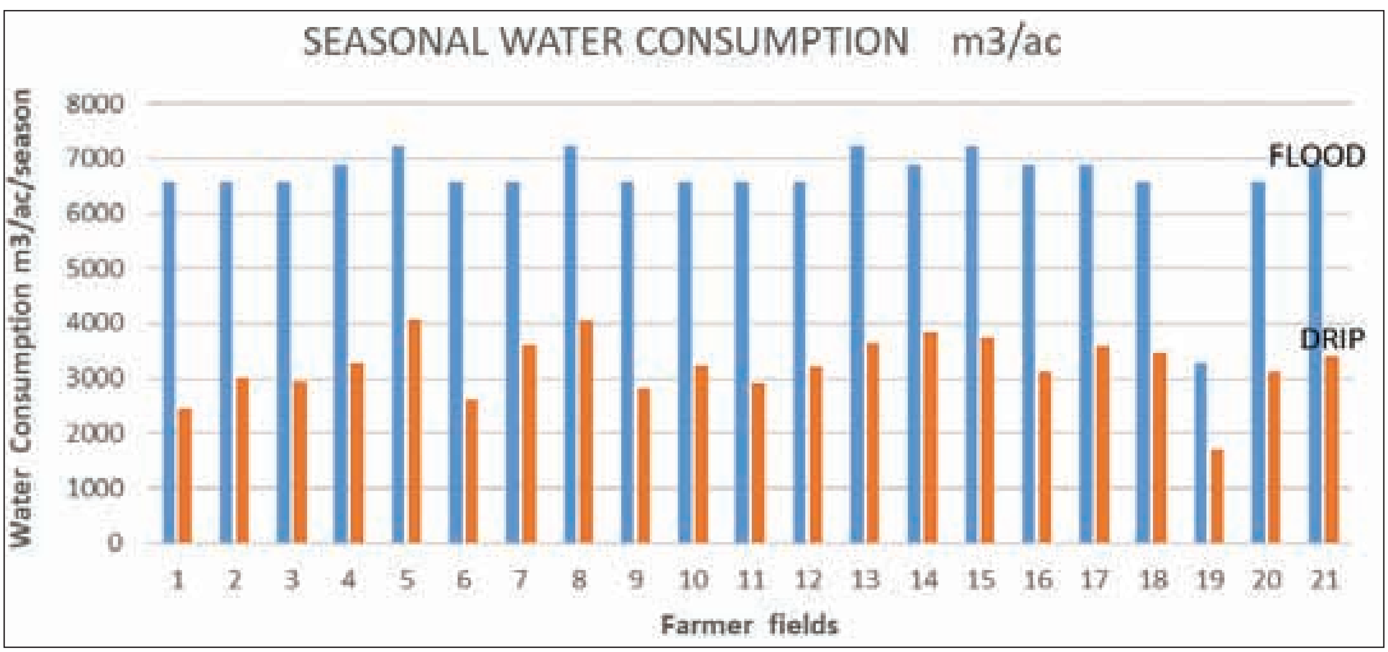

Figure 1: Irrigation water consumption in flood and drip methods of irrigation

Source: (Soman et al 2021)

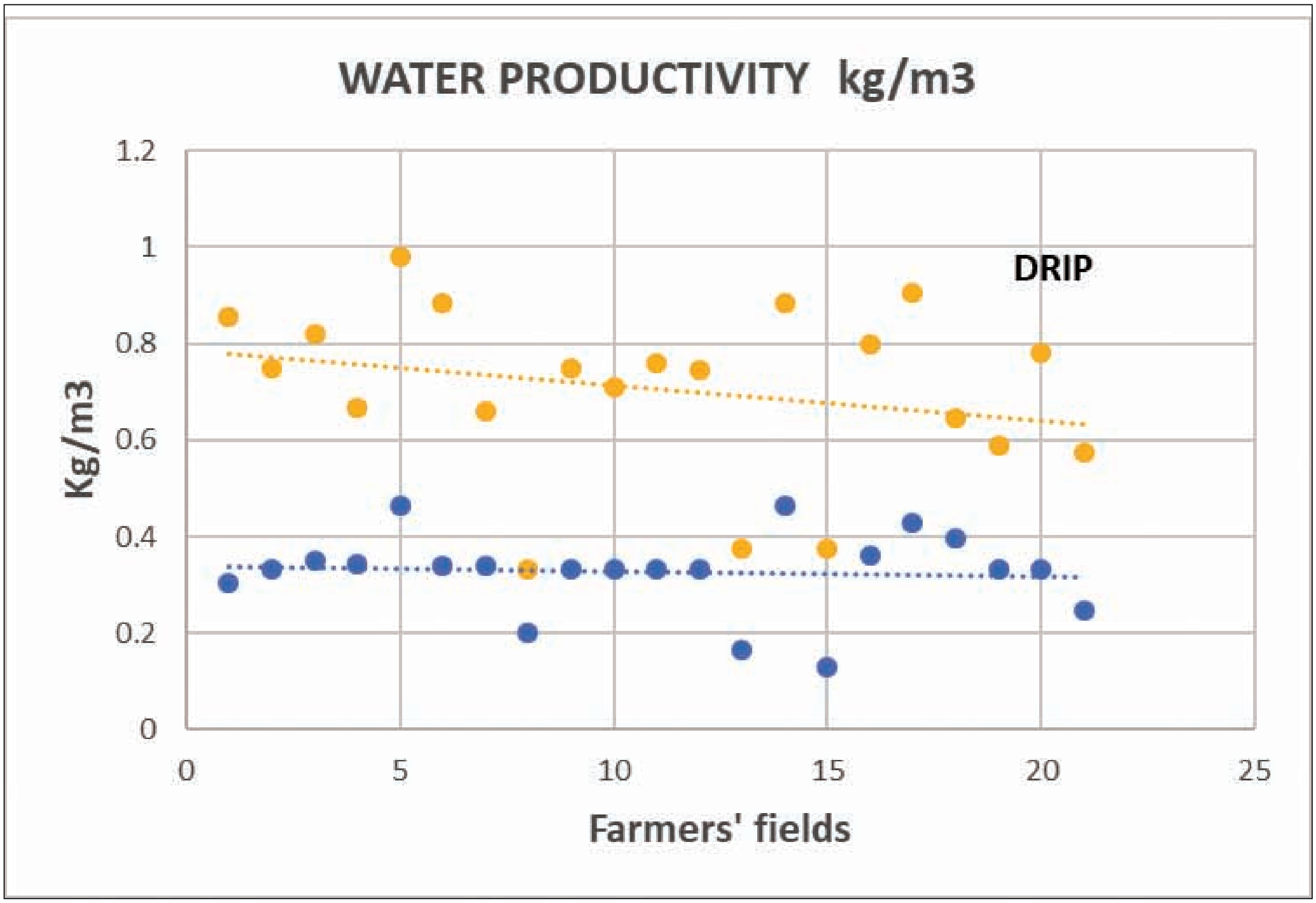

Figure 2: Irrigation water productivity in flood and drip methods of irrigation

Source: (Soman et al 2021)

uses 3434 m^3, and under DSR Flood the water consumption is 6384 m^3 and DSR drip it is 2969 m^3. The savings in water in drip-irrigated rice fields and increased water productivity and grain yields under aerobic rice systems have been already reported by Soman *et al.,* 2018a, and 2018b) and Anusha and Nagaraj 2015.

Irrigation Water productivity (IWP) of rice

The water productivity (based on irrigation water only) was always superior in drip irrigated rice –trending around 0.8 kg paddy grain/m3 as against 0.3 kg/m^3 in flood-irrigated fields (**Figure 2**). Irrigation water productivity (IWP) even of a single variety of rice can't be a constant figure in different locations and under various crop management methods and crop seasons. IWP is also not just dependent on water consumption alone, as other inputs affect productivity. Even in our own work (Soman *et al.*, 2018) the irrigation water productivity obtained in flood and drip irrigated situations differed in absolute values from those obtained in this study. But a comparison of IWP in flood and drip methods of irrigation is relevant for similar crop management situations in the same season.

Rotation crop of wheat planted after the rice harvest.

Under conventional flood, yield of wheat ranged from 3.75 to 5.75 t/ha across different fields; and under drip irrigation it ranged from 4.5 to 6.38 t/ha. The difference in yield expressed both under flood and drip methods of irrigation is not due to the crop variety used, because most of the farmers planted same variety of wheat. Drip irrigation always resulted in higher yield; an overall mean of 13.6% hike in yield of wheat was recorded because of drip irrigation.

Average irrigation water consumption by wheat in flooded fields is 1570 m3/ha/season and in drip fields 1411 m3/ha; unlike in the case of rice, farmers in this district of Haryana, do not keep standing water in wheat fields, hence the flood method of irrigation consumes relatively lower volumes of irrigation water. Drip method reduces the consumption further by 10%.

Conclusion

The summary of the benefits obtained from drip irrigating rice is given below (**Table 4**). Irrigation water consumption is reduced by 51% compared to flood irrigation. There is a slight (3%) difference in water consumption by DSR and TPR methods of planting. Because of heavy rains at the early season the water required for puddling operations were mostly satisfied by rainfall hence the difference between irrigation water consumption by DSR and TPR is very low. Irrigation water productivity improved by more than 100% when drip irrigated.

Table 4. Summary of the benefits from drip irrigating Basmati rice in Haryana in farmers' fields.

Factor	Flood m^3/ac	Drip m^3/ac	Saving m^3/ac	% Saving
Average irrigation water consumption (AVG)	6324.5	3084	3240.5	51%
Transplanted rice	6850	3434	3416	50%
Direct seeding	6384	2969	3415	53%
Water productivity (kg/m^3 water)	0.300	0.800	0.500	63%

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