Feasibility of sprinkler and drip irrigation in transplanted and direct seeded rice (*Oryza sativa* L.) in Haryana

ABSTRACT

On-farm trials on rice crop were conducted at farmer field for three years (2018, 2019 and 2020) to evaluate micro-irrigation (drip and sprinkler irrigation) methods for water use and yield of the crop in comparison to conventional surface irrigation (flooding) method both in transplanted (manually or mechanically) and direct seeded rice so as to determine the feasibility of micro-irrigation in rice to tackle the problem of groundwater depletion in Haryana. In transplanted rice (TPR), grain yield obtained with drip and sprinkler irrigation was statistically similar to that obtained with conventional method. But the yield of direct seeded rice (DSR) increased significantly (15.1- 21.1% increase) when it was irrigated by drip or sprinkler methods than by conventional method. Moreover, the DSR irrigated by drip and sprinkler methods yielded at par with transplanted rice irrigated by any method. The drip and sprinkler methods gave similar grain yield of rice both under transplanted and direct seeded conditions. Manually transplanted crop was comparable to the mechanically transplanted one in respect of quantity of irrigation water applied, total water requirement, water use efficiency and grain yield. The drip irrigated DSR had the lowest irrigation (556-632 mm) and water requirement (778-946 mm), followed by drip irrigated TPR (631-727 mm and 853-1041 mm). The drip and sprinkler irrigation saved 772-925 mm (54.8-57.2%) and 676-800 mm (47.4-49.0%) of irrigation water, respectively over the conventional irrigation in TPR whereas the saving of irrigation water over the conventional method in DSR was 615-720 mm (52.5-53.9%) and 448-532 mm (38.3-39.3%), respectively. Irrespective of establishment techniques, the highest water use efficiency was achieved with drip irrigation (6.73-9.46 kg/ha/mm), followed by sprinkler irrigation (5.66-7.85 kg/ha/mm) whereas it was the lowest with the conventional irrigation (3.28-3.55 kg/ha/mm). It can be concluded from the results that it is feasible to adopt sprinkler irrigation in rice (both in TPR and DSR) as it saved substantial quantity of irrigation water without any penalty in yield and net profit in TPR and even increased the yield and net profit in DSR over the conventional irrigation method. Therefore, sprinkler irrigation can be an effective strategy to manage the depletion of groundwater in Haryana. But the drip irrigation, despite saving more water and being comparable to the sprinkler irrigation in respect of its effect on yield, may not be economically viable due to its higher initial cost.

Key Words: Drip, sprinkler, transplanting, direct seeding, water use efficiency, water saving

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important *Kharif* season food crop in the irrigated areas of north western Indo-Gangetic Plains of India, particularly Punjab and Haryana and plays a vital role in food security of the country. Rice in this region is grown conventionally by transplanting (usually manual) technique of crop establishment. Transplanting can also be done mechanically (by transplanter) which tackles the problem of labour scarcity besides ensuring the desired plant population per unit area (Aggarwal and Singh, 2015). But the transplanted (manually or mechanically) rice requires large quantity of water for

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field preparation (puddling) and maintenance of submergence for most part of the crop growing period. It has been reported that 1357-1666 mm of irrigation water in transplanted rice (TPR) is required to obtain higher yield (Brar *et al*., 2015). The higher water requirement of the crop in Punjab and Haryana is met largely through the use of groundwater as it is the principal source of irrigation in the region. This has led to over-exploitation of groundwater resources as evident from the water table decline at an alarming rate of 0.33 m per year (Narjary *et al*., 2014). Apart from depleting the groundwater resources, it has resulted into higher cost of pumping water (Mahajan *et al*, 2011) due to high cost of installation and maintenance of large pump sets (deep tube wells) as well as high electricity consumption to operate them.

Therefore, there is urgent need to adopt water saving techniques to sustain the rice production while preserving the precious groundwater resources. Direct seeding, a water saving establishment technique of growing rice under unpuddled and unflooded (aerobic) conditions, offers a good alternative to transplanting as it saves extra water required for puddling and maintenance of submerged conditions besides avoiding labour for transplanting. The direct seeded rice (DSR) has been reported to save about 20% of irrigation water over the conventional TPR (Gupta *et al*., 2003). However, possible reduction in the yield of direct seeded high yielding rice cultivars irrigated by conventional flood irrigation (Mahajan *et al*., 2011; Joshi *et al*., 2018) is one of the main obstacles to wide adoption of direct seeding. Moreover, extent of water saved by DSR seems to be insufficient to arrest the depletion of the groundwater to the desired extent.

Therefore, adoption of highly efficient irrigation methods may be the best option to save adequate amount of groundwater used for rice irrigation without sacrificing the crop yield. Use of micro-irrigation methods like sprinkler and drip irrigation in rice can be a pragmatic approach to address the aforesaid concerns as reports from other parts of the country have shown that micro-irrigation can save 40% water over the conventional flooding method in rice (Sharda *et al*., 2017). But there is inadequate information on performance of the sprinkler and drip irrigation in rice in Haryana. The present field experiment was, therefore, conducted to evaluate drip and sprinkler irrigation in rice (both in TPR and DSR) for yield, water use efficiency and economics so as to determine their feasibility for irrigating rice in Haryana

MATERIALS AND METHODS

The field experiment was conducted during *kharif* seasons of 2018, 2019 and 2020 at a farmer's field in village Dera Fateh Singh situated near the town of Pehowa (30^0 04' N, 76^0 78' E, 247 m above mean sea level) in district Kurukshetra, Haryana with facilities of micro-irrigation established by CADA (Command Area Development Authority), Haryana. The soil of the experimental site was clay loam in texture, alkaline in reaction (pH 7.9), low in organic carbon (0.38%), low in available N (140 kg/ha), medium in available phosphorus (15 kg P/ha) and high in available potash (290 kg K/ha). Bulk density of

Commented [i8]: The current field experiment was carried out to assess the effectiveness of drip and sprinkler irrigation methods in rice cultivation (both in TPR and DSR) in terms of yield, water use efficiency, and economic viability. The objective was to determine the suitability of these irrigation techniques for rice cultivation in Haryana.

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the soil was 1.55 g/cc with infiltration rate of 2.8 mm/hr. The experimental site has typical subtropical and semi-arid climate with more than 70% of the total annual rainfall occurring during July to September with August being the wettest month. The daily mean maximum temperature is the highest in June (around 43^{0}C) which drops to about 33^{0}C in October when the rice crop matures whereas daily mean minimum temperature is usually 22^{0}C in October and 32^{0}C in June. The rainfall received during the growing period of the experimental crop was recorded with the help of rain gauge installed at the experimental site and was found to be 328, 222 and 314 mm during 2018, 2019 and 2020, respectively.

The treatments of the experiment consisted of three rice establishment techniques viz. conventional manual transplanting (CMT), mechanical transplanting (MT) and direct seeding (DS) and three irrigation methods viz. sprinkler (SRL), drip (DRP) and conventional surface flooding (CSF). The treatments were laid out in split plot design keeping the establishment techniques in main plots (of size 10500 m^2 each) and the irrigation methods in sub-plots (3500 m^2 each). The experimental area was leveled precisely (by laser leveler) before start of the experiment to ensure uniform application of water. The plots for direct seeding were prepared by ploughing twice with disc harrow and once with power tiller followed by planking while the plots for transplanting (manual or mechanical) were prepared by ploughing twice with disc harrow followed by puddling (twice) and planking (once). Popular high yielding rice varieties of different duration viz. PR 114 (135 days), PR 126 (124 days) and PR 121 (129 days) were used in the study during 2018, 2019 and 2020, respectively. The DSR was sown on May 27, May 30 and June 1 during 2018, 2019 and 2020, respectively by seed cum fertilizer drill in rows 20 cm apart using a seed rate of 20 kg/ha and irrigated with 60 mm water immediately after sowing to provide moisture for germination of seeds. Nursery for manual and mechanical transplanting was sown on the same day (day of DSR sowing) and 10 days later, respectively. In manual transplanting, 30 days old rice seedlings raised in conventional nursery were transplanted in puddled field as per the farmers' practice (18-20 plants or hills/m^2). In mechanical transplanting, 20 days old seedlings (grown on mat type nursery) were transplanted in puddled field by self-propelled paddy transplanter at a spacing of 23.5 x 14 cm (30 hills/m^2).

In micro-irrigation systems, water for irrigation was delivered through PVC pipes after filtering through the screen filter by 7.5 HP motor from the bore well. In drip irrigation system, polyethylene laterals having in-line emitters (40 cm apart with a discharge rate of 2.4 lph) were laid in the field in rows 60 cm apart and the pressure maintained in the system was 1.2 kg/cm^2. In sprinkler irrigation system, mini-sprinklers having wetted radius of 10 m and flow rate of 434 lph were placed in the field at 10 x 10 m spacing with their nozzles mounted at 1.3 m height and were operated a pressure of 2.5 kg/cm^2. In plots to be irrigated with drip and sprinkler methods, the drip and sprinkler systems were laid in the crop field at 15 days after sowing (DAS) in DSR and 15 days after transplanting (DAT) in TPR (manual or

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Commented [i14]: The mean maximum temperature peaks in June at around 43°C, then decreases to about 33°C in October during the rice crop's maturation. Conversely, the mean minimum temperature is usually 22°C in October and 32°C in June. Rainfall during the growth period of the experimental crop was measured using a rain gauge at the site, resulting in 328mm, 222mm, and 314mm in 2018, 2019, and 2020, respectively.

Commented [i15]: The experiment included three different techniques for establishing rice, namely

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Commented [i18]: The Direct Seeded Rice (DSR) was planted

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mechanical) and thereafter drip and sprinkler irrigation were applied to such plots. Before start of the drip and sprinkler irrigation at 15 DAS or 15 DAT, all the plots under DSR received two irrigations (50 mm each) at 5 and 10 DAS whereas all the plots under TPR received frequent light irrigation to maintain shallow submergence (3-5 cm) in the field. In conventional surface flooding method, the plots of DSR, after receiving irrigation at 5 and 10 DAS, were irrigated (50 mm each) at 5 days after disappearance of ponded water (DADPW). The plots of conventionally irrigated TPR, after getting frequent light irrigation for shallow submergence (3-5 cm) up to 15 DAT, received irrigations (50 mm each) at 1 DADPW up to panicle initiation stage and at 2 DADPW thereafter. Irrigation through the drip and sprinkler system was applied at 1 DADPW to the extent that soil got saturated with water and shallow water ponding (1-2 cm) appeared on the soil surface. Irrigation in all the plots was stopped at least a week before the crop maturity.

Fertilizer dose at the rate of 150 kg N (through urea), 60 kg P_2O_5 (through single superphosphate), 60 kg K_2O (through muriate of potash) and 5 kg Zn (through 25 kg zinc sulphate containing 21% Zn) per ha was applied to the crop each year. In both DSR and TPR, full dose of P, K and Zn was applied as basal (at sowing or transplanting). In TPR, N was applied in three equal splits at transplanting, 21 DAT and 42 DAT. In DSR, N was also applied in 3 equal splits at 3, 6 and 9 weeks after sowing. Weeds in TPR were controlled by applying butachlor 1.5 kg/ha at 2-3 DAT but weeds in DSR were controlled by sequential application (spray) of pendimethalin 1.0 kg/ha as pre-emergence and bispyribac sodium 25 g/ha at 25 DAS.

The data on crop parameters viz. number of effective tillers/m^2, grain weight/panicle and grain yield (kg/ha) were recorded at the crop maturity from seven replications or plots (500 m^2 each) of each sub-plot. Number of effective tillers were recorded with a quadrate (0.5 x 0.4 m) placed randomly in each plot. At the same time, ten panicles were also taken randomly from each plot and their grains (obtained after threshing the panicles) were weighed (after drying to 14% moisture) to determine grain weight/panicle. The matured crop from each plot was manually harvested and threshed to record the grain yield/plot and expressed in kg/ha at 14% moisture content. Data on various parameters were analyzed statistically to determine the critical difference (CD) at 5% level of significance (p=0.05) to compare the treatment effects. Quantity of water applied to sub-plots was measured by water meter. Water use efficiency (WUE) was calculated as grain yield per total water received through irrigation and rainfall (Mahajan *et al*., 2011). Production cost of different treatments was worked out with the assumption that salvage value of different components of drip and sprinkler systems will be zero after their useful life (assumed as 10 years). Fixed cost of the micro-irrigation systems per ha per season (assuming two crop seasons per year for 10 years) was determined by the approach of James and Lee (1971) as also used by Singh *et al*. (2020) considering interest rate as 7%. Net return (Rs./ha) was estimated by the difference of

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Commented [i26]: The calculation of water use efficiency (WUE) involved determining gross return (estimated by multiplying grain yield with its minimum support price) and cost of cultivation and was averaged over the three years.

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RESULTS AND DISCUSSION

Grain yield and its attributes

Mean grain yield (averaged over irrigation methods) of rice crop was significantly higher in transplanting (manual or mechanical) than in direct seeding during all the years of study (Table 1) which is attributable to more effective tillers or panicles/m^2 in mechanical transplanting and higher grain weight/panicle in both mechanical and manual transplanting than in direct seeding. The manual transplanting, despite having fewer panicles/m^2 than mechanical transplanting, yielded at par with the latter as it had significantly higher grain weight/panicle. Reduction in grain yield of high yielding rice cultivars under direct seeded conventionally irrigated conditions has also been reported by Kumar and Ladha (2011) and Singh *et al.* (2020). Mean number of effective tillers/m^2 (averaged over establishment techniques) and consequently the mean grain yield was significantly higher with micro-irrigation than with conventional irrigation while the drip and sprinkler irrigation yielded at par with each other during all the years.

Commented [i28]: Throughout the study period (as shown in Table 1), the average grain yield of rice crop was consistently higher when using transplanting methods (either manual or mechanical) compared to direct seeding.

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Commented [i30]: Kumar and Ladha (2011) as well as Singh et al. (2020) have also documented a decrease in grain yield of high yielding rice cultivars when grown under direct seeded conventionally irrigated conditions.

Interaction between the crop establishment techniques and irrigation methods was found to be significant in respect of grain yield (Table 2) which revealed that the grain yield of DSR was significantly higher (15.5-21.1%) when it was irrigated by drip or sprinkler method than by conventional method during all the years of investigation. This might be due to the fact that micro-irrigation supplied water to the plants at the required interval and in desired quantity (Singh *et al*., 2019) whereas the plants irrigated by the conventional method might have suffered due to moisture stress during the period between two irrigations as the water applied by conventional irrigation was subjected to percolation and other application losses in the field. Higher yield of drip irrigated DSR than conventionally irrigated DSR had also been reported by Theivasigamani *et al.* (2016). But the yield of drip and sprinkler irrigated TPR (manual or mechanical) was at par with that of the conventionally irrigated TPR which might be the consequence of higher frequency of irrigation both in conventional and micro-irrigation methods in TPR which avoided water stress to the crop. Moreover, the DSR irrigated with drip or sprinkler methods yielded statistically at par with TPR (manual or mechanical) irrigated by conventional or micro-irrigation methods, indicating that regular supply of moisture through micro-irrigation is needed to prevent the yield penalty in DSR. The lowest grain yield was obtained with DSR when it was irrigated by conventional method. The results are also in agreement with that reported by Sharda *et al*. (2017) and Singh *et al.* (2019).

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Water requirement and water use efficiency

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The quantity of irrigation water applied and total water requirement of the crop (Table 3) varied widely during various years of experimentation, depending upon the varieties or their duration and climatic factors viz. rainfall. The manually transplanted crop was comparable with mechanically transplanted crop in respect of the water applied for irrigation and total water requirement. When averaged over the irrigation methods, quantity of irrigation water applied and total water requirement of the crop was reduced by 11.2-13.8% and 9.0-10.6%, respectively in direct seeding as compared to that in transplanting (CMT or MT) during the three years. Irrespective of the establishment methods, quantity of irrigation water applied as well as total water requirement of the crop was minimum with drip irrigation, followed by that with sprinkler irrigation and maximum with conventional irrigation during all the years of experimentation.

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The drip irrigated DSR had the lowest irrigation (556-632 mm) and water requirement (778-946 mm), followed by drip irrigated TPR (631-727 mm and 853-1041 mm). During various years of experimentation, the drip and sprinkler irrigation saved 772 to 925 mm (54.8 to 57.2%) and 676 to 800 mm (47.4 to 49.0%) of irrigation water, respectively over the conventional irrigation in TPR. However, the savings in applied water in DSR was to the extent of 615 to 720 mm (52.5 to 53.9%) and 448 to 532 mm (38.3 to 39.3%) under drip and sprinkler irrigation, respectively. Accordingly, total water requirement of TPR was reduced by 46.2 to 47.5% and 39.0 to 41.6% under drip and sprinkler irrigation, respectively as compared to conventional irrigation but the reduction in the total water requirement of DSR was 42.8 to 44.1% and 30.8 to 32.1% under drip and sprinkler irrigation, respectively. Total water requirement of both the transplanting techniques was at par obviously due to similar quantity of water applied.

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Water use efficiency varied widely in various years due to variation in yield and water requirement (Table 3). Water use efficiency differed little due to crop establishment techniques but it improved significantly due to micro-irrigation methods. The highest WUE (6.82-9.02 kg/ha/mm) was obtained with drip irrigation, followed by that with sprinkler irrigation (5.80-7.75 kg/ha/mm). The drip irrigation improved the WUE by 196-200% over the conventional flood irrigation whereas improvement in WUE with sprinkler irrigation was 168-171%. The higher WUE in drip and sprinkler irrigation could mainly be attributed to reduced water loss through percolation, seepage and evaporation than in surface flooding method (Fukai and Mitchell, 2022). The WUE obtained with sprinkler irrigation was lesser than that with drip irrigation because of lower efficiency of irrigation as the water sprinkled over the crop was subjected to evaporation losses from air and plant surface. Higher WUE with drip (Sharda *et al.*, 2017 and Fukai and Mitchell, 2022) and sprinkler (Singh *et al.*, 2020) irrigation as compared to conventional irrigation in rice has also been reported earlier.

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Net profit in DSR was significantly higher with sprinkler irrigation than with conventional irrigation (Table 4) which could be attributed to higher yield obtained with sprinkler irrigation which compensated well for cost of the sprinkler system. But in TPR (both manual and mechanical), the net return obtained with sprinkler irrigation was statistically similar to that with conventional irrigation. The suitability of sprinkler irrigation in DSR and in TPR might be attributed to its comparatively lower cost which was well compensated by the additional yield or profit obtained due to sprinkler system. The drip irrigation was, however, least profitable both in DSR and TPR obviously due to its higher cost which could not compensate for the yield advantage. ?

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It can be concluded from the results of the present investigations that it is feasible to adopt sprinkler irrigation for rice in Haryana as it not only saved substantial quantity of irrigation water (38.3–39.3% in DSR and 47.4–49.0% in TPR) but also caused no significant reduction in yield and net profit in TPR and even gave higher yield and net profit in DSR as compared to the conventional irrigation. Therefore, adoption of sprinkler irrigation in rice could be a viable future strategy to manage the depletion of groundwater resources in Haryana. But the drip irrigation, despite saving more water and being as good as the sprinkler irrigation in respect of its effect on rice yield, may not be economically viable due to its higher initial cost. However, keeping in view the greater savings in irrigation water (52.5–53.9% in DSR and 54.4–57.2% in TPR) and hence being more effective in managing the groundwater depletion, drip irrigation also needs to be encouraged in Haryana by providing incentives to the farmers to compensate for its higher cost.

Commented [i46]: adopting sprinkler irrigation for rice cultivation in Haryana is a feasible option.

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Commented [i49]: Therefore, implementing sprinkler irrigation for rice could be a viable strategy to address the depletion of groundwater resources in Haryana. On the other hand, although drip irrigation saves more water and has a similar impact on rice yield as sprinkler irrigation, it may not be economically viable due to its higher initial cost. However, considering the substantial savings in irrigation water (52.5–53.9% in DSR and 54.4–57.2% in TPR) and its effectiveness in managing groundwater depletion, drip irrigation should also be promoted in Haryana. This can be achieved by providing incentives to farmers to offset the higher cost associated with drip irrigation.

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Table 1: Effect of crop establishment techniques and irrigation methods on yield attributes and grain yield of rice crop

Treatment	Number of effective tillers/m^2			Weight of grains/ panicle (g)			Grain yield (kg/ha)		
	2018	2019	2020	2018	2019	2020	2018	2019	2020
Establishment techniques									
DS	263	250	240	3.18	3.68	3.61	5901	6940	6250
MT	301	291	274	2.80	3.41	3.28	6615	7487	6939
CMT	283	274	259	2.64	3.24	3.05	6612	7469	6962
CD (p=0.05)	7	9	12	0.10	0.13	0.08	395	331	286
Irrigation methods									
SRL	288	279	261	2.86	3.48	3.34	6466	7441	6860
DRP	285	276	264	2.93	3.41	3.34	6550	7476	6878
CSF	274	260	247	2.83	3.43	3.27	6111	6980	6414
CD (p=0.05)	10	9	10	NS	NS	NS	292	234	288

CMT: DS: direct seeding; MT: mechanical transplanting; CMT: conventional manual transplanting; SKL: sprinkler; DRP: drip; CSF: conventional surface flooding

Table 2: Effect of various irrigation methods on grain yield (kg/ha) of rice under different crop establishment techniques

Establishment techniques (E)	Irrigation methods (I)								
	2018			2019			2020		
	SRL	DRP	CSF	SRL	DRP	CSF	SRL	DRP	CSF
DS	6244	6276	5184	7215	7358	6248	6572	6664	5516
MT	6599	6715	6530	7530	7563	7368	6971	6968	6878
CMT	6556	6660	6620	7577	7507	7324	7035	7003	6848

CD (p=0.05) for interaction (E x I) 524 (2018), 420 (2019), 510 (2020)

Table 3: Irrigation water applied, total water requirement and water use efficiency of rice as influenced by irrigation methods under different crop establishment techniques

Establish-ment techniques (E)	Irrigation methods (I)											
	2018				2019				2020			
	Irrigation water applied (mm)											
	SRL	DRP	CSF	Mean	SRL	DRP	CSF	Mean	SRL	DRP	CSF	Mean
CMT	800 (48.3)	662 (57.2)	1548	1003	743 (48.0)	646 (54.8)	1430	940	853 (48.3)	727 (56.0)	1651	1077
MT	793 (47.4)	660 (56.3)	1509	987	727 (47.5)	631 (54.4)	1403	920	836 (49.0)	711 (56.5)	1636	1061
DS	766 (38.9)	577 (53.9)	1253	865	723 (38.3)	556 (52.5)	1171	817	820 (39.3)	632 (53.3)	1352	935
Mean	786	633	1437		731	611	1335		836	690	1546	
Total water requirement (mm)												
CMT	1128 (39.9)	990 (47.2)	1876	1331	965 (41.6)	868 (47.5)	1652	1162	1167 (40.6)	1041 (47.0)	1965	1391
MT	1121 (39.0)	988 (46.2)	1837	1315	949 (41.6)	853 (47.5)	1625	1142	1150 (41.0)	1025 (47.4)	1950	1375
DS	1094 (30.8)	905 (42.8)	1581	1193	945 (32.1)	778 (44.1)	1393	1039	1134 (31.9)	946 (43.2)	1666	1249
Mean	1114	961	1765		953	833	1557		1150	1004	1860	
Water use efficiency (kg/ha/mm)												
CMT	5.66	6.94	3.28	5.29	7.63	9.46	4.48	7.19	5.80	7.05	3.31	5.38
MT	5.93	6.80	3.55	5.43	7.94	8.87	4.53	7.11	6.06	6.80	3.53	5.46
DS	5.81	6.73	3.53	5.36	7.85	8.65	4.43	6.98	6.03	6.73	3.48	5.41
Mean	5.80	6.82	3.45		7.81	8.99	4.48		5.96	6.86	3.44	
CD (p=0.05) for E: NS (for all the years); CD (p=0.05) for I: 0.24 (2018), 0.23 (2019), 0.24 (2020); CD (p=0.05) for E x I: NS (for all the years)												

Figures in parentheses show the water saved (%) by drip and sprinkler irrigation over conventional irrigation in the same establishment technique

Table 4: Effect of irrigation methods on average (over 3 years) net profit (Rs./ha) under different crop establishment techniques (Rs./ha)

Establishment techniques (E)	Irrigation methods (I)			
	SRL	DRP	CSF	Mean
DS	50875	42902	40433	44737
MT	47513	38189	53304	46335
CMT	46816	36914	52596	45442
Mean	48401	39335	48778	

CD (p=0.05) for E: NS; CD (p=0.05) for I: 3293; CD (p=0.05) for interaction (E x I): 5858