Growth, Yield and Yield Contributing Factors of Rice Crop as Influenced by Different Level and Methods of Irrigation in Tarai Region of Uttarakhand, India

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A B S T R A C T

The present study was undertaken with a view to study the effect of different level of irrigation on biometric parameters of rice crop such as growth, yield and yield attributes and water use efficiency under surface and subsurface drip irrigation. The results shows that the biometric parameters such as plant height, number of tillers per plant, plant dry matter and LAI for rice crop were found maximum in the treatments T_3 (subsurface drip) and T_8 (conventional irrigation). Water supply to the crops was significantly higher in the treatment T_8 as compared to other treatments. The crop yield was found to be maximum in treatments T_8 followed by T_7 and T_3. Whereas, the water use efficiency for treatments under drip irrigation was significantly superior to the treatments under conventional irrigation.

Introduction

The available fresh water resources in the world are constant and the population is continually increasing, this available water per capita will continue to decrease resulting in stress or water scarcity in some areas.

Rice (*Oryza sativa*) is the most important human food crop in the world, directly feeding more people than any other crop. Rice has also fed more people over a longer time than has any other crop. It is spectacularly diverse, both in the way it is grown and how it is used by humans. This is the staple food of those people which living in the eastern and the southern parts of the country, particularly in the areas having over 150 cm annual rainfall. As of 2009 world food consumption of rice was 531.61 million metric tons of paddy equivalent (354,60281 of milled equivalent), while the remote largest consumers were China consuming 156.31 million metric tons of paddy equivalent (29.4 percent of the world consumption) and India consuming 123.5 million metric tons of paddy equivalent (23.28% of the world consumption) (FAO 2012). Drip irrigation is a

type of micro- irrigation that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation rate. Drip irrigation systems distribute water through a network of direction and flow control valves, pipes, tubing, and emitters or drippers. Depending on how well designed, installed, maintained, and operated it is, a drip irrigation system can be more efficient than other types of irrigation systems, such as surface irrigation or sprinkler irrigation.

The main objectives of this study to investigate growth, yield and yield contribute factors as influenced by different level and method of irrigation.

Materials and Methods

Study area, climate and soil characteristics

The present study was conducted at G.B. Pant University of Agriculture and Technology, Pantnagar (29˚N latitude, 79˚30´E longitude and 243.83 m above mean sea level) in Uttarakhand state of India which comes under *Tarai* region, located in foothills of the Himalayas. The study area comes under Agro- climatic zone 14 and 9. The experimental fields of 1000 square meter at the Vegetable Research Centre (VRC), G.B Pant University of Agriculture and Technology Pantnagar, Uttarakhand was selected to conduct various field experiments. The experimental field has drip irrigation as well as surface irrigation facility. The meteorological data such as temperature, relative humidity, wind speed, rainfall, pan evaporation and sunshine hours during the crop period was acquired from the meteorological observatory located at Crop Research Centre (CRC), Pantnagar which is 5 km away from the experimental site. The

average annual rainfall was 1400 mm with the monsoon season generally from June to September month. The summer is too dry and hot, and the winter is very cold. The dry season starts from November and ends in May. The mean monthly temperature ranges from 5˚C to 25˚C while the mean maximum temperature varies from 20˚C to 40˚C.The experimental site consists of silty clay loam with sand (14%), silt (54%) and clay (32%). The average bulk density of the experimental site was determined using core sampler. The average bulk density was found to be 1.45 g/cm^3. The soil moisture content before and after irrigation and at field capacity was determined by soil moisture meter (TDR 300) and calibrated with gravimetric method at regular interval of time. The field capacity was found to be 42 percent by volume basis.

Drip irrigation scheduling of rice crop

The crop water requirement was calculated by following formula as given in INCID, (1994). The total water applied to the rice crop is calculated as:

$$V= \sum (E_p \times K_p \times K_c \times S_p \times S_r \times WP + ER)$$

Where,

V = estimated crop water requirement at 100% water use level, litre/day/plant

Epan = Pan Evaporation, mm/day Kp = Pan coefficient
Kc = Crop coefficient
Sp = Plant to plant spacing, m Sr = Row to row spacing, m
Wp = Percentage wetted area, 90% ER = Effective rainfall, mm

In this study calculation of crop coefficient, K_c, for rice crop was done on the basis of Agromet Advisory Service Bulletin, GBPUA&T, Pantnagar The value of crop

coefficient for initial stage $K_{c\ nit}$ was taken as 0.8, for mid stage $K_{c\ mid}$ was taken as 1.7 and for end stage it was taken as $K_{c\ end}$ as 0.7.

Based on USDA. S.C.S method the effective rainfall (ER) is calculated on monthly basis as:

$$ER = P_t \left[\frac{125 - 0.2 \times P_t}{125} \right]$$ for Pt < 250mm Where, P_t - total rainfall, mm

The drip irrigation system with a mainline of a PVC pipe of 40 mm diameter having wall thickness of 1.8 mm and pressure rating up to 6 kg/cm^2 was laid.

The lateral turbo line having 16 mm diameter was provided with drippers of 1.3 lph discharge capacity with minimum pressure of 1 kg/cm^2 spaced at 30 cm. In this study drip lines (lateral) were laid parallel to the crop rows and one drip line served two rows of crop.

The duration of water application to each treatment was controlled with the help of delivery valves provided at inlet of each laterals. Under drip irrigation treatments soil moisture was maintained near field capacity with the help of frequently application of water at 3-7 days interval.

Experimental treatments for rice crop

T1: V - Volume of water application under surface drip irrigation in DSR planted at 20 cm row spacing

T2: 1.2V - Volume of water application under surface drip irrigation in DSR planted at 20 cm row spacing

T3: 1.2V - Volume of water application under subsurface drip irrigation in DSR planted at 20 cm row spacing

T4: V - Volume of water application under surface drip irrigation in DSR planted at 15 cm row spacing

T5: 1.2V - Volume of water application under surface drip irrigation in DSR planted at 15 cm row spacing

T6: 1.2V - Volume of water application under subsurface drip irrigation in DSR planted at 15 cm row spacing

T7: Surface irrigation (soil moisture maintained at saturation) in DSR planted at 20 cm row spacing

T8: Conventional flood irrigation (Standing Water) in TPR planted at 20 cm row spacing

Test crop, preparation of experimental plot, fertilizer application and fertigation

Rice (*Oryza sativa*), variety HKR-47 was selected as test crop for study. Deep ploughing (20-25 cm) of field was done with soil turning plough. In subsurface drip irrigation treatments, lateral (turbo line) were laid at 20 cm below ground surface**.** At the inlet of drip line (turbo line) lateral valve were provided to start and stop the irrigation.

With the row spacing of 20 cm and 15 cm the rice seeds were directly sown on 22th of June 2015 in direct seeded rice (DSR) treatments. Later the transplantation of nursery raised rice seedlings were done on 15th July 2015 with the row spacing of 20 cm in transplanted rice treatment replications. Recommended dose of N: P_2O_5: K_2O, 120:60:40 kg/ha were supplied during the crop period which was based on soil analysis.

At the time of sowing and just before transplanting, the 25% of recommended dose of nitrogen and total quantities of P_2O_5 and K_2O along with 25 kg/ha of zinc (Zn) were applied**.** The harvesting of the crop was started on 31th October 2015. The harvesting

was finished by 2nd November, 2015. From each plot, the crop and straw yield was recorded separately and then converted to per hectare basis.

Biometric observations recorded in rice crop

Five plants were randomly selected from each replication and selected plants were tagged by aluminium tag for identification. For taking biometric observations, different parameters of vegetative growth such as plant height, number of tillers per plant, number of shoots per m^2, leaf area index, plant dry matter and yield and yield contributing characters were recorded at 30, 60, 90 DAS and at harvest.

Statistical analysis

In this study analysis of variance technique was used to analyse the experimental data to randomized block design with the help of computer. The critical differences at 5% level of probability were calculated for testing the significance of difference between the treatments.

Results and Discussion

In this study effects of treatments on all the characters were found to be significant.

The highest average plant height (Table 4.1) at 30 and 60 DAS was recorded for T_3 (1.2V - Volume of water application under subsurface drip irrigation in DSR planted at 20 cm row spacing) with value of 36 cm and 70 cm, respectively. While average plant height at 90 days after sowing and at harvest was found to be highest for T_8 (Conventional flood irrigation (Standing Water) in TPR planted at 20 cm row spacing) with value of 96 cm and 103 cm, respectively. The result revealed that the significant influence of sub surface drip irrigation with 20 cm row spacing over submerged irrigation at 30 and 60 DAS on

plant height while the TPR with saturated level of irrigation under surface irrigation showed significant influence on plant height entire the growing period of crop.

Number of tillers per plant

At 30 DAS the number of tillers per plant was found to be almost similar for all the treatments except treatments T_6, T_7, T_8 (Table 3.2).

At 60, 90 DAS and at harvest the highest number of tillers per plant was recorded for with value of 12, 11, 10, respectively. Thus, result showed that the number of tillers per plant in transplanted rice (TPR) was significantly superior to direct seeded rice (DSR).

Leaf Area Index (LAI)

The highest leaf area index at 30 DAS was recorded for the treatment T_8 (1.16 m^2 m^{-2}) followed by T_7 (1.1 m^2 m^{-2}). AT 60, 90, and at harvest, the highest LAI was recorded again in T_8 followed by T_7 and T_1 (Table 3.3). Thus, result showed that TPR with submerged irrigation was significantly superior to DSR under drip. This result revealed that the plant leaf growth was affected by water and moisture availability.

Plant dry matter

At 30, 60 and 90 DAS the plant dry matter was recorded maximum for treatment T_5 (182 g m^{-2}), T_3 (463 g m^{-2}) and T_6 (1946 g m^{-2}), respectively. At harvest the plant dry matter was found to be highest for the treatment T_8 (2070 g m^{-2}) (Table 3.4).

This result showed that TPR with submerged irrigation was significantly superior to DSR under drip and DSR with saturated level of irrigation.

Yield and yield contributing characters

The number of productive tillers/hill and panicle length were recorded highest for treatment T_8 followed by T_2 and T_3. The analysis of the data revealed that the number of panicles and grains per plant were recorded highest for the treatment T_8 followed by T_7.

The weight of 1000 grains was highest for treatment T_8 with a value of 40.8 gm followed by T_7 and T_3 (Table 3.5) Thus, this result showed the method of irrigation such as surface irrigation, surface drip irrigation and subsurface drip irrigation significantly influenced the crop yield and all yield contributing characters. Similar result was also reported by *Ayars et al.,* (1999) based on his study on subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. The result revealed that the grain yield was observed maximum for the treatment T_8 (7.9 t/ha) followed by treatment T_7 (7.1t/ha) and treatment T_3 (6.9 t/ha) and minimum for treatment T_4 (5.4t/ha). Similar results were reported by other researchers (Tabbal *et al.,* 2002, Bouman *et al.,* 2005) between continuous and intermittent irrigation. The straw yield was observed maximum for the treatment T_8 (12.1 t/ha) followed by treatment T_7 (11.1 t/ha) and the minimum for T_1 (8.6 t/ha). In this study harvesting index was recorded highest for the treatment T_3 (42.5%) and lowest for treatment T_4 (35.5%). Thus, the overall result revealed that treatments T_8 (Conventional flood irrigation (Standing Water) in TPR planted at 20 cm row spacing) and T_3 (1.2V - Volume of water application under subsurface drip irrigation in DSR planted at 20 cm row spacing) were significantly superior to other treatments.

The effect of irrigation regimes and method of irrigation on water use efficiency (WUE) was significant T_1 to T_8 with 0.018 to 0.0621 t/ha-cm m (Table 3.6). The water use efficiency was found to be highest for the treatment T_3 with a value of 0.0621 t/ha-cm, followed by treatment T_6 with a value of 0.0620 t/ha-cm. Surface irrigation under treatment T_8 i.e. TPR with continuous soil submergence produce lowest WUE but in the treatment T_7 i.e. surface irrigation in DSR with saturated soil increases the WUE (Table 4.9). In this study the amount of water needed to grow one kg of rice was found to be lowest for treatment T_3 with a value of 1607 litres of water, followed by treatment T_6 with a value of 1611 litres of water and highest for treatment T_8 with a value of 5508 litres of water. Thus, the overall result showed that the effective use of water as well as effective water management under surface and subsurface drip irrigation over surface irrigation.

Field investigations was undertaken to investigate the growth yield and yield contribute factor as influenced by different level and method of irrigation at the experimental farm of Vegetable Research Centre, GBPUA&T, Pantnagar, Uttarakhand. The highest average plant height at 30 and 60 DAS was recorded for T_3 (1.2V - Volume of water application under subsurface drip irrigation in DSR planted at 20 cm row spacing) with a value of 36 cm and 70 cm, respectively. While average plant height at 90 days after sowing and at harvest was found to be highest for T_8 (Conventional flood irrigation (Standing Water) in TPR planted at 20 cm row spacing) with a value of 96 cm and 103 cm, respectively. At 30 DAS the number of tillers per plant was found to be almost similar for all the treatments except treatments T_6, T_7, T_8. At 60, 90 DAS. At harvest, the highest number of tillers per plant was recorded for T_8 (Conventional flood irrigation (Standing Water) in TPR planted at 20 cm row spacing) with a value of 12, 11, 10, respectively.

Table.1 Effect of various treatments on plant height of rice crop (cm) at
different stages of crop growth

Treatment	Plant Height (cm)			
	Days after sowing (DAS)			
	30	60	90	At Harvest
T₁	29	68	82	93
T₂	34	66	84	90
T₃	36	70	84	91
T₄	34	68	82	92
T₅	34	66	86	90
T₆	33	67	78	87
T₇	33	66	92	100
T₈	31	70	96	103
CD (P<0.05)	6.3	6.5	9.85	10.1
SEM (±)	0.83	1.06	2.1	1.5
CV (%)	7.1	4.4	7	5

Table.2 Effect of various treatments on number of tillers per plant of rice crop at different stages
of crop growth

Treatment	Number of tillers per plant			
	Days after sowing (DAS)			
	30	60	90	At harvest
T₁	4	10	9	8
T₂	4	9	9	9
T₃	4	8	8	7
T₄	4	9	8	8
T₅	4	7	7	6
T₆	3	9	8	7
T₇	3	8	7	7
T₈	5	12	11	10
CD (P<0.05)	1.1	4.9	1.6	1.2
SEM (±)	0.23	0.70	0.56	0.45
CV (%)	17.2	22.2	19.0	16.5

Table.3 Effect of various treatments on leaf area index (LAI) of rice crop at different stages of crop growth

Treatment	Leaf Area Index (LAI)			
	Days After sowing (DAS)			
	30	60	90	At Harvest
T_1	0.95	2.12	4.57	3.4
T_2	0.91	2.08	4.31	3.22
T_3	0.87	2	4.21	3.02
T_4	0.905	2.02	4.35	3.06
T_5	0.86	2.01	4.2	3.15
T_6	0.92	2.07	4.32	3.1
T_7	1.1	2.2	4.6	3.25
T_8	1.16	2.92	4.78	3.9
CD (P<0.05)	0.12	0.18	0.32	0.46
SEM (±)	0.05	0.12	0.10	0.10
CV (%)	14.9	16.4	6.40	8.70

Table.4 Effect of various treatments on plant dry matter of rice crop at different stages of crop growth

Treatment	Plant dry matter (g m^{-2})			
	Days after sowing (DAS)			
	30	60	90	At Harvest
T_1	113	362	1341	1778
T_2	147	411	1427	1890
T_3	122	463	1229	1759
T_4	155	419	1680	2315
T_5	182	415	1890	2472
T_6	158	373	1946	2560
T_7	134	398	1195	1640
T_8	149	338	1582	2070
CD (P<0.05)	74.6	102.3	186.2	285.1
SEM (±)	9.93	19	3.6	3.8
CV (%)	19.2	13.9	9.7	7.4

Table.5 Effect of various treatments on yield contributing characters of rice at harvest

Treatment	No. of Productive tillers/plant	No. of grains/plant	Panicle Length (cm)	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvesting index (%)
T₁	8	642	25.6	38.1	6.1	8.6	41.5
T₂	9	697	26	39.2	6.5	9.2	41.4
T₃	7	704	29.2	39.8	6.9	9.3	42.5
T₄	8	631	25.06	36.2	5.4	9.8	35.5
T₅	6	651	25.3	36.9	6.0	10.4	36.5
T₆	7	679	25.1	38.3	6.4	10.8	37.2
T₇	7	743	26.06	40.2	7.1	11.1	39.01
T₈	10	812	29.7	40.8	7.9	12.1	39.5
CD (P<0.5)	1.2	213.2	2.8	3.8	1.4	1.6	9.2
SEM (±)	0.50	21.64	0.84	0.729	0.26	0.42	1.04
CV (%)	18.2	8.8	9.02	5.4	9.9	11.9	6.9

**Table.6** Water use efficiency of rice under different level of irrigation

Treatment	Total irrigation water applied (mm)	Effective rainfall (mm)	Total amount of water applied (mm)	Total Water saving (%)	Water use efficiency (t/ha-cm)	Amount of water to produce unit yield (l/kg)
T₁	261.2	796	1057.2	75.7	0.0576	1733
T₂	313.4	796	1109.4	74.5	0.0585	1706
T₃	313.4	796	1109.4	74.5	0.0621	1607
T₄	195.8	796	991.8	77.2	0.0544	1836
T₅	235.1	796	1031.1	76.3	0.0581	1718
T₆	235.1	796	1031.1	76.3	0.0620	1611
T₇	2222	796	3018	30.6	0.0235	4250
T₈	3555.5	796	4351.5		0.0181	5508
CD (P<0.5)					0.21	
SEM (±)					0.075	
CV (%)					17.4	

Fig.1 Effect of different levels of irrigation on plant height of rice crop
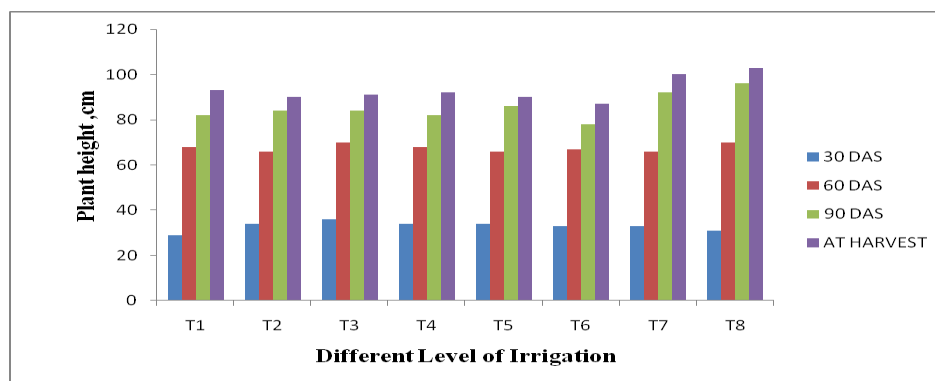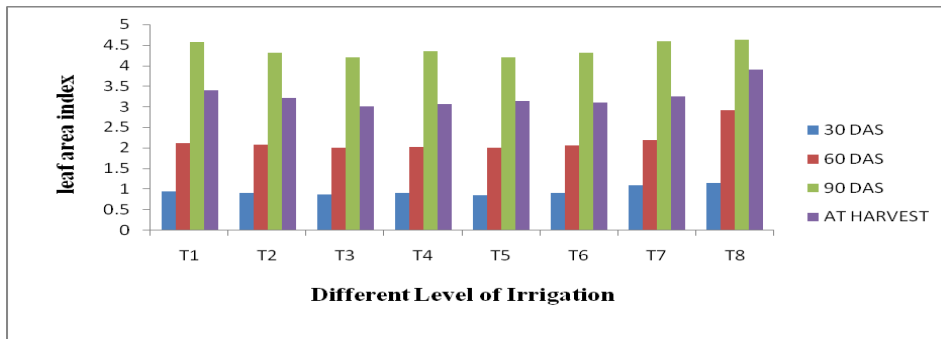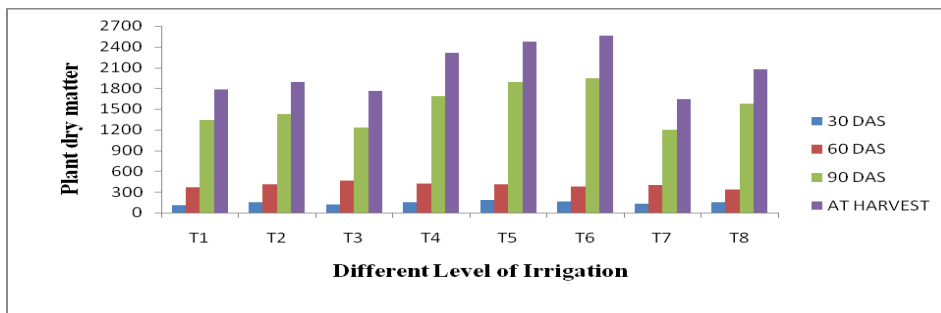
Fig.2 Effect of different levels of irrigation on tillers per plant for rice crop
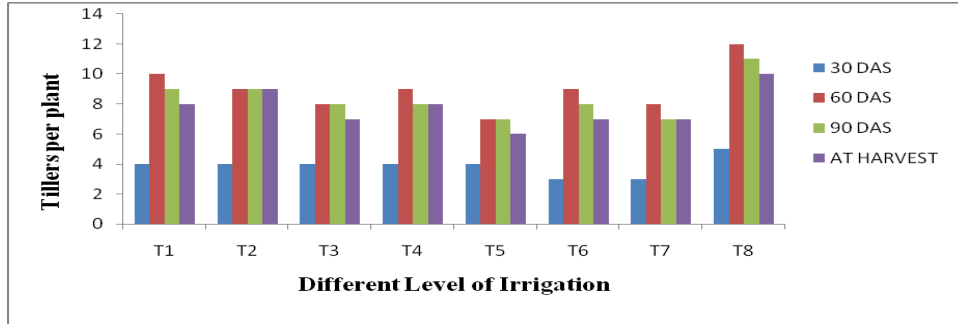
Fig.3 Effect of different levels of irrigation on leaf area index (LAI) for rice crop

Fig.4 Effect of different levels of irrigation on plant dry matter for rice crop

Plate.1 Rice crop under drip irrigation at 15 and 30 DAS

Plate.2 Rice crop at 90 DAS and at harvest

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The highest leaf area index at 30 DAS was recorded for the treatment T_8 (1.16m^2 m^{-2}) followed by T_7 (1.1 m^2 m^{-2}). AT 60, 90, and at harvest the highest LAI was recorded again in T_8 (4.78 m^2 m^{-2}) followed by T_6 (4.6 m^2 m^{-2}). Thus, result showed that TPR with submerged soil irrigation was significantly superior to DSR under drip irrigation. In case of plant dry matter the effect of different level of irrigation was found to be significant at all different DAS. At 30, 60 and 90 DAS the plant dry matter was recorded maximum for treatment T_5 (182 gm^{-2}), T_3 (463 gm^{-2}) and T_6 (1946 gm^{-2}), respectively. At harvest, the plant dry matter was found to be highest for the treatment T_8 (2070 gm^{-2}). The number of productive tillers/hill and panicle length were recorded highest for treatment T_8 followed by T_2 and T_7.

The analysis of the data revealed that the number of panicles and grains per plant were recorded highest for the treatment T_8 followed by T_7 and T_3. The weight of 1000 grains was highest for treatment T_8 with a value of 40.8 gm followed by T_3 and T_2. The grain yield was observed maximum for the treatment T_8 (7.9 t/ha) followed by treatment T_7 (7.1t/ha) and treatment T_3 (6.9 t/ha) and minimum for treatment T_4 (5.4t/ha). The straw yield was observed maximum for the treatment T_8 (12.1 t/ha) followed by treatment T_7 (11.1 t/ha) and the minimum for T_1 (8.6 t/ha).In this study harvesting index was recorded highest for the treatment T_3 (42.5%) and lowest for treatment T_4 (35.5%).

The water saving over submerged soil irrigation under surface irrigation (TPR) was found to be highest for treatment T_4 with a value of 94.4 %, followed by treatment T_1 with a value of 92.6 % and lowest for treatment for T_7 with a value of 37.4 %. During entire growing period of crop the total irrigation water applied for the treatments T_1, T_2, T_4, T_5 under surface drip irrigation and for the treatments T_3, T_6, under subsurface drip irrigation was 261.2, 313.4, 195.8, 235.1 and 313.4, 235.1 mm, respectively. Similarly total irrigation water applied for the treatments T_7 and T_8 under surface irrigation was 2222 and 3555.5 mm, respectively The water use efficiency was found to be highest for treatment T_3, followed by treatment T_6 and lowest for treatment T_8. In this study the amount of water needed to grow one kg of rice was found to be lowest for treatment T_3 with a value of 1603 litres of water, followed by treatment T_6 with a value of 1611 litres of water and highest for treatment T_8 with a value of 5508 litres of water.

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