ESTIMATION OF CROP WATER REQUIREMENT FOR SUMMER RICE UNDER DRIP IRRIGATION SYSTEM IN TARAI REGION OF UTTARAKHAND

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ABSTRACT

This study was undertaken to investigate the response of different level of irrigation on crop growth, yield and water use of summer rice crop. Further, field investigation was also undertaken to estimation of crop water requirement for summer rice under drip irrigation system.The results were compared with the surface irrigation treatments. The present study for summer rice crop shows that the total irrigation water applied throughout the growing period of crop for treatment T_1, T_2, T_3, T_4, T_5 and T_6 under drip irrigation was 75.76, 60.60, 90.88, 92.89, 74.31 and 111.47 mm respectively. Similarly, total water applied for T_7 (TPR) and T_8 (TPR) with submerged irrigation under surface irrigation was 1166 and 1555mm. The water saving in treatments T_1 to T_6 under drip irrigation over submerged irrigation was found to be 95.12 to 92.83 percent and water saving in treatment T_7 TPR with saturated level at 20 × 20 cm spacing under surface irrigation over TPR with submerged irrigation was found to be 25.01 percent. The result revealed that more water saving occurs in drip irrigation. The growth parameters such as plant height, number shoot per m^2 were found maximum in the treatments T_7 (TPR at 20 × 20 cm spacing under surface irrigation) at 30, 60 DAS and in treatment T_3 at 60, 90 DAS and at harvest respectively. The maximum tillers per plant was observed in treatment T_2 (0.8V (TPR) with drip irrigation 20×20cm spacing under drip irrigation) at 60, 90 DAS and at harvest. The maximum grain yield was observed 4.2 t/ha in treatment T_8 followed by treatment T_3 (3.05 t/ha), T_7 (4.1t/ha). The minimum yield was observed in T_6 (2.1 t/ha).whereas, the values of water use efficiency obtained ranges from 0.19 t/ha-cm to 0.44 t/ha-cm. The amount of water needed to grow one kg of rice was lowest under treatment T_2 with a value of 2249 liters of water, and highest under treatment T_8 with a value of 5165 liters.

INTRODUCTION

In the world, water resources are abundant. The increasing water demand for domestic use has adverse effects on agricultural development, as the knowledge of common people on optimal water use is limited and common irrigation methods for most of the crops, like summer paddy, monsoon paddy, wheat etc. are wild flooding, border, basin, and furrow irrigation methods with very low irrigation efficiency and high water demand. Under such irrigation conditions, the crops especially paddy is regarded as a high water-consuming crop, hindering its development in areas with limited water resource availability. It is therefore, essential to formulate an economically viable water and other input management strategies in order to irrigate more land area with existing water resources and to enhance crop productivity. Also, the improper distribution of water is lowering the conveyance efficiency and field application and ultimately causing the loss of irrigation water. Thus, right amount and frequency of irrigation is vital for optimum use of limited water resources for crop production and management.

Rice (*Oryza sativa*), member of grass family is the staple food and about 530 million ton per year rice is produced globally. It is an important target to provide food security and livelihoods for millions. More than 90% of the world's rice production is consumed in Asia and much of the rice crop is grown under irrigation. Over 80% of Asia's freshwater resources available for irrigation are used in crop production and about 50% of this is used in rice (Dawe et al. 1998). It is a water-intensive crop and occupies just about 30% of the cultivable area but consumes nearly 70 % of available water. Also, when it comes to water productivity in paddy, India's is the lowest in the world, at 150 grams of paddy per 1,000 liters, resulting in an average output of 2.1 tonnes per hectare.

Drip irrigation

Drip irrigation is a method of irrigation with high frequency application of water in and around the root zone of plants (crop) and consist of network of pipes with suitable emitting device. It is also known as trickle irrigation was first used in mid 1960s but its wide scale adoption commenced in 1970s, when it was first used on 56,000ha area. Currently, more than 6 million hectares have been covered under micro irrigation world over. The highest coverage is in America (1.9 mha) followed by Europe and Asia (1.8 mha), Africa (0.4 mha), and Oceania (0.2 mha).

Objectives of the study

There are not many research studies and other related technical literature and standards regarding drip irrigation for summer rice.Therefore, some research is required to determine the water requirement at different level of drip irrigation for summer rice crop. Water is one of the most important inputs essential for plant growth. Right amount of water at right time in right manner at right place leads to improved water productivity and resource saving

Keeping above in view an attempt has been made to study the response of different level of irrigation for summer rice crop. Further, field investigation was also undertaken to estimate crop water requirement for summer paddy crop grown at experimental area of college of technology , GBPUA&T, Pantnagar under different level of irrigation. Keeping all the above cited issues in mind the present work "**ESTIMATION OF CROP WATER REQUIREMENT FOR SUMMER RICE UNDER DRIP IRRIGATION SYSTEM IN TARAI REGION OF UTTARAKHAND**" has been undertaken with the following objectives:

1. To compare the effects of different level of irrigation on crop growth, crop yield and water use efficiency of summer rice crop.
2. To estimate crop water requirement for summer rice under drip irrigation system.

MATERIALS AND METHODS

The present study was undertaken with a view to compare the effects of different level of irrigation on crop growth, yield and water use efficiency for summer rice crop.

The various field experiments were undertaken to study the response of drip irrigation on crop growth, yield, water saving , water use and water use efficiency for summer rice crop.

Study Area, Climate and Soil Characteristics

The study area comes under climatic zone of western Himalayan region and is located in the Shivalik foothills of the Himalayas and represents the *Tarai* region of Uttarakhand state. The study area comes under Agro-climatic zone 14 and 9.The field experiment was conducted at the college of technology GBPUA&T Pantnagar, Uttarakhand, located at 29˚N latitude, 79˚30´E longitude and at an altitude of 243.83 m above mean sea level. The meteorological data such as temperature, relative humidity, wind speed, sunshine hours, rainfall and pan evaporation during the crop period was obtained from the meteorological observatory located at Crop Research Centre, Pantnagar about 2 km away from the experimental site.

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 1.3 g/cm^3. The field capacity was found to be 40 percent by weight basis.

Effect of Different Level of Irrigation on Crop Growth, Yield

To study the effect of different level of irrigation on crop growth, for summer rice an experimental set up and layout was created. The details of experimental design and layout are presented in the following section.

Experimental plan and layout – Summer Rice

A field of 358 area was divided into eight equal plots of 20m x 1.8m. The experiment was laid out in randomized block design having 8 treatments. 0.5m meter gap between each plot was left to avoid the effect of irrigation treatments. The layout of the experiment is presented in Fig. 3.1. The variety of the rice crop was HKR-47. The method used for summer rice sowing in all treatments was transplanted. The plant to plant and row to row spacing varied according to the treatments. Treatments 1 to 6 were grown under drip irrigation. The treatment details of the experiment are presented in Table 3.1.

Drip irrigation scheduling of summer rice crop

The daily crop water requirement/volume of water to be applied was estimated using the following relationship as given in INCID, (1994). The total water applied to the crop is calculated as

$$V = \sum (E_p \times K_c \times K_p \times S_p \times S_r \times WP + ER) \quad \ldots(3.1)$$

Where,

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

Epan = Pan Evaporation, mm

Kc = Crop coefficient

Kp = Pan coefficient

Sp = Plant to plant spacing, m

Sr = Row to row spacing, m

Wp = Percentage wetted area, 90%

ER = Effective rainfall, mm

The crop coefficient, K_c, for rice crop was calculated on the basis of

Agromet Advisory Service Bulletin, GBPUA&T, Pantnagar (Table.A.1). The crop coefficient K_c values are varying with the type of crop, its growing stage, growing season and prevailing weather conditions. The shape of the curve represents the changes in vegetation and ground cover during crop development and maturation that affect the ratio of ET_c or ET_0.

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

$$ER = P_t \left[\frac{125 - 0.2 \times Pt}{125} \right] \quad \text{for } Pt < 250\text{mm} \quad \dots (3.1.1)$$

Where,

P_t - total rainfall, mm

The drip irrigation system was laid with a mainline of a PVC pipe of 40mm diameter having wall thickness of 1.8mm and pressure rating up to 4 Kg/cm^2. The 16 mm diameter pipes having inline drippers of 30cm spacing and emission rate of 1.3 l/h were used as dripline. The drip lines were laid parallel to the crop rows and each drip line served two rows of crop. The duration of delivery of water to each treatment was controlled with the help of valves provided at inlet of each laterals. In case of surface irrigation, scheduling for transplanted rice (TPR) the crop was kept submerged in water. The discharge in both the irrigation was measured on volumetric basis.

Agronomic details

Test crop

Summer Rice (*Oryza sativa*), variety HKR-47 selected as test crop for the study.The variety released in November 2005 is a medium dwarf variety with long, sleek, golden yellow grains. Leaves are straight and dark green in colour. It is suitable for early as well as late sowing.

Preparation of land

The field was ploughed deep (20-25 cm) with soil turning plough. Thereafter the plots were prepared manually by spade. The layout of the experiment was prepared according to the experimental plan.

Transplanting

The rice seeds were sowing in the nursery on 4th feb 2015. Later the nursery raised rice seedlings were transplanted on 15th march 2015 with the spacing according to the treatment .

Fertigation

Based on soil analysis recommended dose of $N:P_2O_5:K_2O$, 120:60:40 kg/ha were supplied during the crop period. The 25% of recommended dose of N and total quantities of P_2O_5 and K_2O along with 25 kg/ha of Zn were applied at the time of sowing and just before transplanting. The remaining quantity of N was supplied in two equal instalments at active tillering and 5-7 days before panicle initiation stage .After 60 days of sowing 4 kg of $N:P_2O_5:K_2O$ (20:20:20) and 2 kg of urea were supplied and broadcasted as per treatments. 1 kg of urea was broadcasted and 4 kg of urea was supplied through drip after 75 and 95 days after sowing.

Weed control

Submergence of rice field by irrigation helps in weed control therefore, for the treatments in which rice crop was grown under drip irrigation, weed control happened to be an important acultutural operation. A chemical pendimethalin @ 5ml/l of water was sprayed immediately after sowing for the control of weeds and 6 times the hand weeding was done in all the plots which were under drip irrigation in the interval of 15 days after sowing. There were hardly any weeds in the plots under surface irrigation

Crop protection measures

The crop was supervised regularly. Based on observed symptoms for fungus, bacteria and insects the protection or control measures were taken.

Observations recorded in summer rice crop

Five plants were randomly selected from each plot 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 shoots per m^2, number of tillers per plant, and yield and yield contributing characters were recorded.

Plant height

The plant height of selected plants was recorded at 30 days interval in each replication of different treatments. The plant height was recorded from the bottom of the plant to the highest leaf of the individual plant. The plant height was recorded at 30 DAS, 60 DAS, 90 DAS and at harvest.

Number of shoots per m^2

$1m^2$ area was marked in each treatment and number shoots within that area were recorded at 30 DAS, 60 DAS, 90 DAS and at harvest.

Number of tillers per plant

The number of tillers in selected plants was recorded at 30 DAS, 60 DAS, 90 DAS and at harvest in each replication of different treatments.

Yield and yield contributing characters

Number of productive tillers, panicles per plant, number of grains per plant, ear length and 1000 grains weight were recorded at and after harvest in each replication of different treatment

Table 3.1. Experimental details of drip and surface method of irrigation in rice crop

Irrigation Treatments	Details of irrigation
T_1	V at 20 × 20 cm spacing (TPR) under drip irrigation
T_2	0.8V at 20 × 20cm spacing (TPR) under drip irrigation
T_3	1.2Vat 20 × 20 cm spacing (TPR) under drip irrigation
T_4	V at 15 × 20 cm spacing (TPR) under drip irrigation
T_5	0.8V at 15 × 20cm spacing (TPR) under drip irrigation
T_6	1.2Vat 15 × 20 cm spacing (TPR) under drip irrigation
T_7	TPR with saturated level of soil moisture at 20 × 20 cm spacing under surface irrigation
T_8	TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation

Plate. 4.1. Summer Rice crop under Drip Irrigation at 15 DAS

Plate. 4.1. Summer Rice crop under Drip Irrigation at 90 DAS

RESULTS AND DISCUSSION

Water requirement and water economy of summer rice crop under different level of irrigation

Water requirement

The experiment was started for summer rice in the month of March 2015. Various level of irrigation water was applied according to the estimated daily crop water requirement/volume of water, for the drip irrigation treatments. Table 4.1 represents amount of irrigation water applied at different level of irrigation. The total irrigation water applied throughout the growing period of crop for treatment T_1, T_2, T_3, T_4, T_5 and T_6 under drip irrigation was 75.76, 60.60, 90.88, 92.89, 74.31 and 111.47 mm respectively. Similarly, total water applied for T_7 TPR and T_8 TPR with submerged irrigation under surface irrigation was 1166 and 1555mm.

Water saving

The data pertaining to the water saving due to drip irrigation over surface method of irrigation is given in Table 4.1. The water saving in treatments T_1 to T_6 under drip irrigation over submerged irrigation was found to be 95.12 to 92.83 percent and water saving in treatment T_7 TPR with saturated level at 20 × 20 cm spacing under surface irrigation over TPR with submerged irrigation was found to be 25.01 percent. Water saving due to drip irrigation was obviously because of water application directly into plant root zone at frequent intervals through network of pipes with no water loss in field application. And water saving in treatment T_7 under surface method of irrigation was because; the water was maintained up to saturation level of soil moisture.

Response of Different Level of Irrigation on Biometric Growth, Yield and Water use of summer Rice crop under Drip Irrigation

Various crop biometric parameters, yield attributes, water use as influenced by different level of drip irrigation in combination with surface irrigation were investigated, which has been described in the following sections.

Effect of different level of irrigation on biometric parameters of summer rice under drip irrigation

The effect of different levels of irrigation on biometric parameters such as plant height, number of shoots per m^2, number of tillers per plant, yield were analyzed. The experimental results of these biometric observations are presented in Table 4.2 to 4.7

Plant height

The plant height of tagged plants was measured at 30, 60, 90 days after sowing (DAS) and at harvest (Table 4.2). The result revealed that the average plant height at 30 DAS and 60 DAS was significantly higher in treatment T_7 (TPR at 20 × 20 cm spacing under surface irrigation) compared with the rest of the treatments and treatment T_7 and T_8 (TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation) showed significantly higher average plant height at 90 DAS and at harvest. There was significant influence of drip irrigation with larger 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 throughout the growing period of crop.

Number of shoots per m^2

Number of shoots was recorded within the marked 1 m^2 area at 30, 60, 90 days after sowing (DAS) and at harvest (Table 4.3). The effect of different treatments on shoot per m^2 was found to be significant at all different DAS. At 30 DAS the shoot per m^2 was observed maximum in the T_6 (1.2V at 15 × 20 cm (TPR) spacing under drip irrigation) which was 27.5 percent higher than T_8 (TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation). At 60, 90 DAS and at harvest T_3 (1.2V at 20 × 20 cm spacing (TPR) under drip irrigation) showed significantly higher shoots per m^2 which was 66.6, 45.9 and 41.6 percent respectively higher than T_8. Thus, the significant influence of drip irrigation over submerged irrigation on number shoots per $m^2$was observed.

Number of tillers per plant

The data pertaining to number of tillers per plant are summarized in table 4.4. The effect of different treatments on tillers per plant was found to be significant at all different DAS. At 30 DAS maximum number of tillers per plant was observed in treatment T_3 (1.2V (TPR) with drip irrigation at 20×20cm spacing under drip irrigation) . At 60, 90 DAS and at harvest the maximum tillers per plant was observed in treatment T_2 (0.8V (TPR) with drip irrigation at 20×20cm spacing under drip irrigation).

Yield contributing characters

The data of yield contributing character that is number of productive tillers, number of panicles per plant, number of grains per plant, panicle length (cm) and 1000 grain weight (g) are presented in Table 4.5. The effects of treatments on all the characters were found to be significant. The data recorded for number of productive tillers/hill and panicle length were found almost similar in all the treatments with maximum in treatment T_8 (16 productive tillers and 28 cm panicle length). The number of panicles and grains per plant were found to be maximum in treatment T_8 followed by T_7 and T_1. The last yield contribute, 1000 grain weight was also found to be maximum in treatment T_8 followed by T_3 and T_5. Thus, this result showed the significant influence of TPR with submerged irrigation on all the yield contributing characters over drip and TPR with saturated level of irrigation.

Grain yield, straw yield

The data of grain yield, straw yield are presented in Table 4.6. The effects of treatments on grain yield were found to be significant. The maximum grain yield observed was 4.2 t/ha in treatment T_8 followed by (3.05 t/ha) T_7 (4.1t/ha). The minimum yield was observed in T_6 (2.1 t/ha). The straw yield was also found significant for all the effects of treatments and was observed maximum in T_5 (10.34 t/ha) followed by T_2 (9.34 t/ha) and the minimum was observed in T_6 (9.18 t/ha).

Water use efficiency

T for water use efficiency, shown in Table 4.7. The values obtained ranges from 0.19 t/ha-cm to 0.44 t/ha-cm. The water use efficiency was highest (0.44 t/ha-cm) for treatment T_2 (0.8V at 20 x 20 cm under (TPR) drip irrigation) followed (0.42 t/ha-cm) for T_3 (1.2V at 20 x 20 cm (TPR) under drip irrigation) and lowest (0.19 t/ha-cm) for T_8 (TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation). The results clearly indicate that the drip irrigation method has significantly increased the water use efficiency.

Table 4.8 shows the data related to amount of water used to produce unit yield of rice under different treatments. The amount of water needed to grow one kg of rice was lowest under treatment T_2 with a value of 2249 liters of water, followed by treatment T_3 with a value of 2343 liters and highest under treatment T_8 with a value of 5165 liters.

The increased water use efficiency under drip irrigatihon is because of drip system that provides precise and measured quantity of water to individual plant. The saving of water combined with higher yield under drip irrigation are the reasons for increased water use efficiency. On the other hand surface irrigation has lowest water use efficiency. It is because of surface irrigation is associated with many losses like evaporation losses, seepage losses, deep percolation losses etc.

Table 4.1. Amount of total irrigation water applied in summer rice at different level of irrigation and corresponding water saving as compared to submerged irrigation

Treatment	Total irrigation water applied (mm)	Water saving (%)
T_1 V at 20 × 20 cm spacing (TPR) under drip irrigation	75.76	95.12
T_2 0.8V at 20 × 20cm spacing (TPR) under drip irrigation	60.60	96.10
T_3 1.2Vat 20 × 20 cm spacing (TPR) under drip irrigation	90.88	94.15
T_4 V at 15 × 20 cm spacing (TPR) under drip irrigation	92.89	94.02
T_5 0.8V at 15 × 20cm spacing (TPR) under drip irrigation	74.31	95.22
T_6 1.2Vat 15 × 20 cm spacing (TPR) under drip irrigation	111.47	92.83
T_7 TPR with saturated level of soil moisture at 20 × 20 cm spacing under surface irrigation	1166	25.01
T_8 TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation	1555	

Table 4.2. Effect of various treatments on plant height of summer rice crop (cm) at different stages of crop growth

Treatment	Plant Height (cm)			
	Days after sowing (DAS)			
	30	60	90	At Harvest
T_1	43	49	97	103
T_2	43	54	92	99
T_3	41	55	96	100
T_4	42	54	98	102
T_5	44	58	94	98
T_6	42	55	98	101
T_7	47	59	102	105
T_8	46	58	104	107

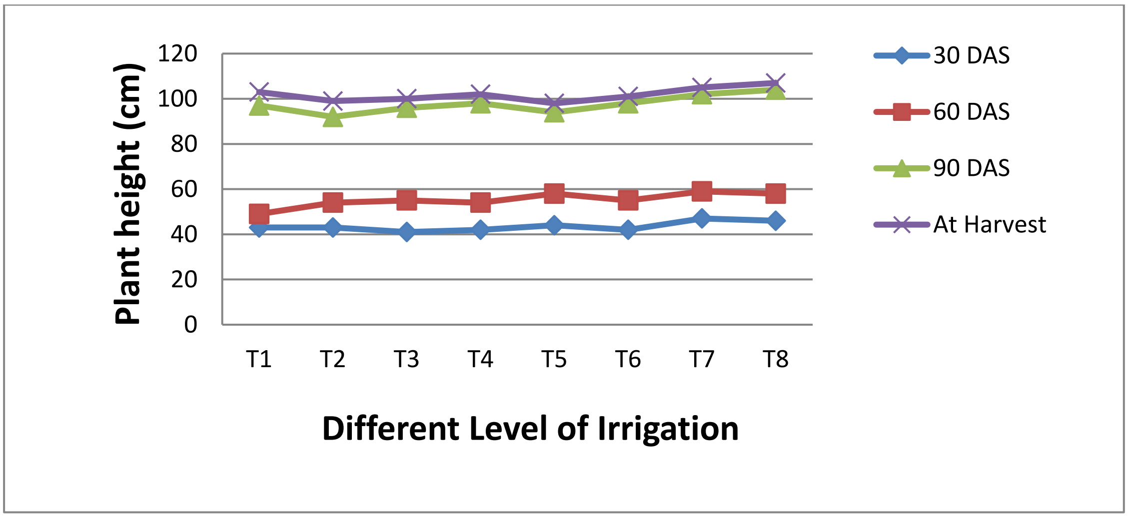

Fig. 4.1. Effect of different levels of irrigation on plant height of summer rice crop

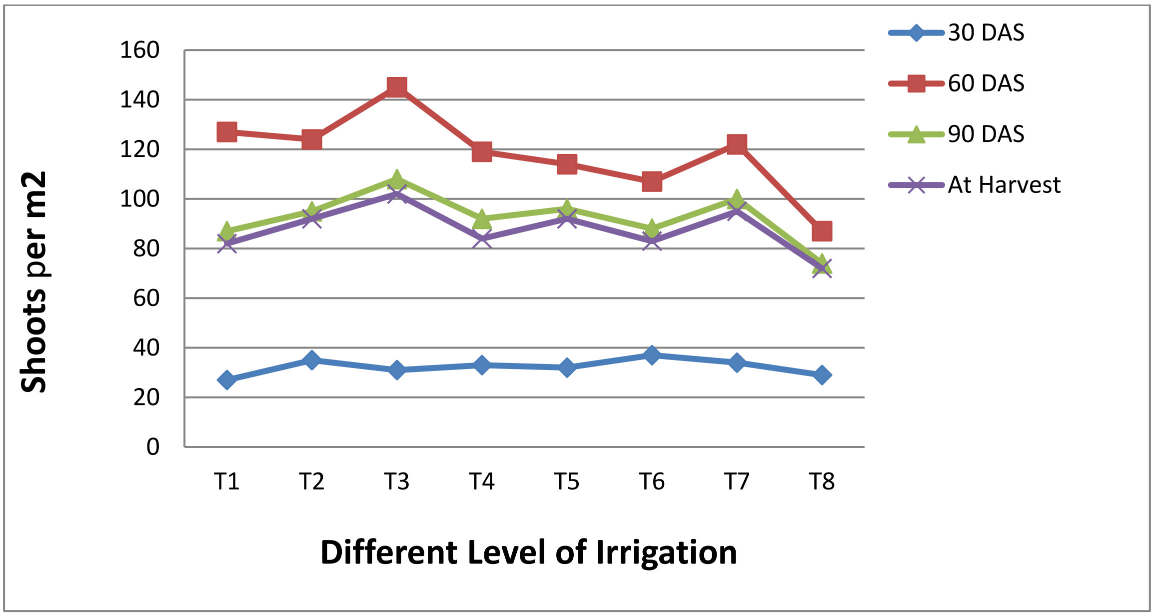

Fig. 4.2. Effect of different levels of irrigation on shoots per m^2 for summer rice crop

Table 4.3. Effect of various treatments on number of shoots per m^2 of summer rice crop at different stages of crop growth

Treatment	Number of Shoots per m^2			
	Days after sowing (DAS)			
	30	60	90	At Harvest
T_1	27	127	87	82
T_2	35	124	95	92
T_3	31	145	108	102
T_4	33	119	92	84
T_5	32	114	96	92
T_6	37	107	88	83
T_7	34	122	100	95
T_8	29	87	74	72

Table 4.4. Effect of various treatments on number of tillers per plant of summer rice crop at different stages of crop growth

Treatment	Number of tillers per plant			
	Days after sowing (DAS)			
	30	60	90	At harvest
T_1	9	20	22	19
T_2	10	29	31	27
T_3	15	27	29	25
T_4	10	26	24	22
T_5	13	28	25	24
T_6	10	24	28	26
T_7	8	25	23	21
T_8	11	15	18	16

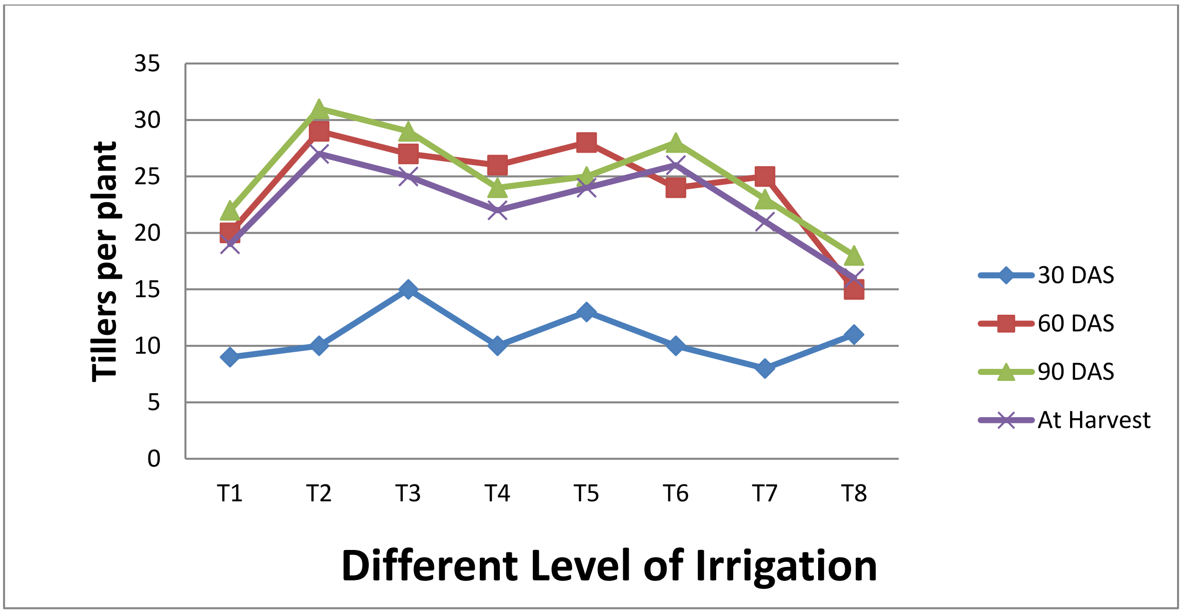

Fig. 4.3. Effect of different levels of irrigation on tillers per plant for summer rice crop

Table 4.5. Effect of various treatments on yield contributing characters of summer rice crop at harvest

Treatment	No. of productive tillers/hill	No. of panicles/plant	No. of grains/plant	Panicle length(cm)	1000 grain weight(g)
T_1	11	117	337	21	23.6
T_2	12	112	307	20	23.7
T_3	10	111	298	21	24.3
T_4	11	116	267	23	23
T_5	11	112	257	24	23.9
T_6	12	117	230	22	23.2
T_7	11	118	351	21	34
T_8	16	124	367	28	35

Table 4.6. Effect of various treatments on grain yield, straw yield and harvesting index of summer rice crop

Treatment	Grain yield (t/ha)	Straw yield (t/ha)
T_1	2.8	8.49
T_2	3	9.34
T_3	3.01	9
T_4	2.5	8.72
T_5	2.45	10.34
T_6	2.1	9.18
T_7	4.1	8.42
T_8	4.2	9.20

Table 4.7. Water use efficiency of summer rice under different level of irrigation

Treatment	Total irrigation water applied (mm)	Effective rainfall (mm)	Total amount of water applied (mm)	Water use efficiency (t/ha-cm)	amount of water to produce unit yield (l/kg)
T_1	75.76	614.39	690.5	0.40	2466
T_2	60.60	614.39	674.89	0.44	2249
T_3	90.88	614.39	705.27	0.42	2343
T_4	92.89	614.39	707.28	0.35	2829
T_5	74.31	614.39	688.7	0.36	2811
T_6	111.47	614.39	725.86	0.28	3456
T_7	1166	614.39	1780.39	0.23	4342
T_8	1555	614.39	2169.39	0.19	5165

Summary and Conclusions

Keeping in view the importance of drip irrigation for higher water use efficiency with minimum resource use, the present investigation was undertaken to study the response of different level of irrigation on summer rice crop. Further, field investigation was also undertaken to estimation of crop water requirement for summer rice crop under drip irrigation in tarai region of uttrakhand at the experimental farm of college of technology, GBPUA&T, Pantnagar. The salient aspects of results of the study are summarized under following sections:

Response of Different Level of Irrigation on Biometric Growth, Yield and Water use on Summer Rice Crop.

Various biometric growth parameters, yield its attributes, as influenced by different level of irrigation were investigated

1. The plant height of tagged plants was measured at 30, 60, 90 days after sowing (DAS) and at harvest (Table 4.1). The result revealed that the average plant height at 30 DAS and 60 DAS was significantly higher in treatment T_7 (TPR at 20 × 20 cm spacing under surface irrigation) compared with the rest of the treatments and treatment T_7 and T_8 (TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation) showed significantly higher average plant height at 90 DAS and at harvest. There was significant influence of drip irrigation with larger 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 throughout the growing period of crop.
2. Number of shoots was recorded within the marked 1 m^2 area at 30, 60, 90 days after sowing (DAS) and at harvest (Table 4.2). The effect of different treatments on shoot per m^2 was found to be significant at all different DAS. At 30 DAS the shoot per m^2 was observed maximum in the T_6 (1.2V at 15 × 20 cm (TPR) spacing under drip irrigation) which was 27.5 percent higher than T_8 (TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation). At 60, 90 DAS and at harvest T_3 (1.2V at 20 × 20 cm spacing (TPR) under drip irrigation) showed significantly higher shoots per m^2 which was 66.6, 45.9 and 41.6 percent respectively higher than T_8. Thus, the significant influence of drip irrigation over submerged irrigation on number shoots per $m^2$was observed.
3. The data pertaining to number of tillers per plant are summarized in table 4.3. The effect of different treatments on tillers per plant was found to be significant at all different DAS. At 30 DAS maximum number of tillers per plant was observed in treatment T_3 (1.2V (TPR) with drip irrigation at 20×20cm spacing under drip irrigation) . At 60, 90 DAS and at harvest the maximum tillers per plant was observed in treatment T_2 (0.8V (TPR) with drip irrigation at 20×20cm spacing under drip irrigation).
4. The data of yield contributing character that is number of productive tillers, number of panicles

per plant, number of grains per plant, panicle length (cm) and 1000 grain weight (g) are presented in Table 4.6. The effects of treatments on all the characters were found to be significant. The data recorded for number of productive tillers/hill and panicle length were found almost similar in all the treatments with maximum in treatment T_8 (7 productive tillers and 26 cm panicle length). The number of panicles and grains per plant were found to be maximum in treatment T_8 followed by T_7 and T_1. The last yield contribute, 1000 grain weight was also found to be maximum in treatment T_8 followed by T_4 and T_1. Thus, this result showed the significant influence of TPR with submerged irrigation on all the yield contributing characters over drip and TPR with saturated level of irrigation.

5. The data of grain yield, straw yield are presented in Table 4.7. The effects of treatments on grain yield were found to be significant. The maximum grain yield observed was 4.2 t/ha in treatment T_8 followed by (3.05 t/ha) T_7 (4.1t/ha). The minimum yield was observed in T_6 (2.1 t/ha). The straw yield was also found significant for all the effects of treatments and was observed maximum in T_5 (10.34 t/ha) followed by T_2 (9.34 t/ha) and the minimum was observed in T_6 (9.18 t/ha).
6. The water use efficiency is defined as the relationship between units produced and volume of water applied. The effect of the various treatments was found to be significant for water use efficiency, shown in Table 4.8. The values obtained ranges from 0.19 t/ha-cm to 0.44 t/ha-cm. The water use efficiency was highest (0.44 t/ha-cm) for treatment T_2 (0.8V at 20 x 20 cm under (TPR) drip irrigation) followed (0.42 t/ha-cm) for T_3 (1.2V at 20 x 20 cm (TPR) under drip irrigation) and lowest (0.19 t/ha-cm) for T_8 (TPR with submerged irrigation at 20 × 10 cm spacing under surface irrigation). The results clearly indicate that the drip irrigation method has significantly increased the water use efficiency.
7. Table 4.8 shows the data related to amount of water used to produce unit yield of rice under different treatments. The amount of water needed to grow one kg of rice was lowest under treatment T_2 with a value of 2249 litres of water, followed by treatment T_3 with a value of 2343 litres and highest under treatment T_8 with a value of 5165 litres. The method of irrigation has significantly affected water use efficiency.
8. The increased water use efficiency under drip irrigation is because of drip system that provides precise and measured quantity of water to individual plant. The saving of water combined with higher yield under drip irrigation are the reasons for increased water use efficiency. On the other hand surface irrigation has lowest water use efficiency. It is because of surface irrigation is associated with many losses like evaporation losses, seepage losses, deep percolation losses etc.
9. In this study it was found that the drip irrigation system is not suitable for heavy soil like clay soil. Due to high soil moisture tension in summer season the soil was cracked under drip irrigation consequently less amount of irrigation water accumulated on the soil surface.

REFERENCES

Pereira, L.S., Cordery, I., Iacovides, I., 2012. Improved indicators of water use performance and productivity for sustainable water conservation and saving. *Agricultural Water Management.* 108 : 39–51.

Perry, C., Steduto, P., Allen, R.G., Burt, C.M., 2009. Increasing productivity in irrigated agriculture: agronomic constraints and hydrological realities. *Agricultural Water Management.* 96 :1517–1524.

Qayoom, S., Khanday, B.A., Lone, B.A., Singh, P., Singh, L., Singh, G., P., Narinder, G., M.A. and Singh, K.K. 2014. Evaluation of CERES-Rice model (DSSAT 4.5) for simulating the response of rice (*Oryza sativa*) cultivars to age of seedlings in temperate Kashmir, *Indian Journal of Agronomy,* 59 (2) : 261-266.

Arif, C., Setiawan, B. I., Sofiyuddin, H. A., Martief, L. M., Mizoguchi, M. And Doi, R. 2012. Estimating Crop Coefficient in Intermittent Irrigation Paddy Fields Using Excel Solver. *Rice Science,* 19(2): 143−152.

Azam, A., Crout, S.N., Bradley, R.G. 1994. Perspectives in modeling resource capture by crops. In: Monteith, J.L., Unsworth, M.H., Scott, R.K. (Eds.), Resource Capture by Crops, *Proceedings of the 52nd Univ. of Nottingham Eastern School. Nottingham University Press*, pp. 125-14.

Behera, S.K. and Panda, R.K. 2009. Integrated management of irrigation water and fertilizers for wheat crop using field experiments and simulation modelling. *Agricultural Water Management*, 96 : 1532–1540.

Belder, P., Bouman, B.A.M., Cabangon, R., Guoan, Lu., Quilang, E.J.P., Yuanhua, Li., Spiertz, J.H.J. and Tuong, T.P. 2004. Effect of water-saving irrigatioon rice yield and water use in typical lowland conditions in Asia. *Agricultural Water Management*, 65 : 193–210.

Borojeni, B. H. and Salehi, F. 2013. Effect of continuous and intermittent irrigation methods on rice (cv. Koohrang) yield. *Archives of Agronomy and Soil Science*, 59(7): 947–954