Journal Crop and Weed, 11(Special Issue):118-123(2015)

Effect of irrigation scheduling and weed management practices on performance of lowland transplanted rice

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Received:18-09-2014; Revised:16-10-2014; Accepted:15-12-2014

ABSTRACT

Field experiment was conducted using split-plot design during boro season of 2012-13 and 2013-14, to study the influence of different irrigation scheduling and weed management practices on growth, yield and water use efficiency of lowland transplanted rice. The experimental results revealed that among the irrigation regimes, continuous submergence of 5±2 (I1) gave the significantly higher growth and yield attributing characters resulted in maximum grain yield 6471 kg ha^{-1} with low water use efficiency 5.0 kg ha^{-1} mm^{-1} (pooled of 2 yrs). Continuous saturation treatment (I5) gives just 7.82% less grain yield with high water use efficiency 13.7 kg ha^{-1} mm^{-1} (pooled of 2 yrs) than the I1 treatment. Whereas among the weed management practices, weed-free check followed by W3-Pretilachlor 50% EC on 1 DAT + hand weeding on 40 DAT, W5-Hand weeding twice on 20 and 40 DAT and W4-Bispyribac sodium 10% SC on 20 DAT + hand weeding on 40 DAT gave significantly higher growth, yield attributing characters and yield with high water use efficiency.

Keywords: Irrigation, rice, water use efficiency, weed management

Rice (*Oryza sativa* L.) is a principal source of food for more than half of the world population especially in Southeast Asia. Rice is the most important agricultural ecosystem and present and future food security of the country mostly depends on it. Rice area in our country is about 43 million ha with production of 101 million tonnes in the year 2012 (FAO, 2012).

Boro is a winter season, photo-insensitive, transplanted rice cultivated with supplemental irrigation. With the increase in irrigation facilities, boro crop is now being taken in areas outside its traditional boundaries and a new cropping system is emerging. Even a marginal increase in the productivity of *boro* rice in Eastern India will significantly increase the total rice production in the country (Singh, 2002).

Worldwide, about 93 million ha of irrigated lowland rice provide 75% of the world's rice production. Rice is a large water consumer, but water for rice production is increasingly becoming scarce and expensive due to the increasing demand for water from the ever-growing population, competition from other sectors, such as urbanization, tourism, industry and ecosystem services (Loeve *et al*., 2007). Traditionally rice is grown under a continuously flooded condition and hence most conventional water management practices aim to maintain a standing depth of water in the field throughout the season. Decreasing water availability for agriculture threatens the productivity of irrigated rice ecosystem, ways must be sought to save irrigation water and maintain potential yield of rice (Bouman *et al*., 2007). The success of water saving irrigation methods implementation for reducing water losses through seepage and percolation, since the hydrostatic pressure can significantly reduced compared to continuously flooded irrigation field (Kukal *et al*., 2005).

In rice culture, water and weeds are often considered to be closely interlinked. Yield reductions caused by uncontrolled weed growth throughout a crop season have been estimated to be from 44 to 96%, depending on the rice culture (Ampong-Nyarko and De Datta, 1991).

Hence the present study was undertaken to investigate the influence of different irrigation scheduling and weed management practices on growth, yield and water use efficiency of lowland transplanted rice.

MATERIALS AND METHODS

A field experiment was conducted at Balindi research complex of Bidhan Chandra Krishi Viswavidyalaya during *boro* season of 2012-13 and 2013-14. The farm is located in the New Alluvial Zone of West Bengal at 22^{o} 572 N latitude, 88^{o} 322 E longitude and at an altitude of 9.75 m above mean sea level. The soil of the experimental field was deep clayey with moderate drainage and with pH (6.53 and 6.52), organic carbon (0.75 and 0.72%), during 2012-13 and 2013-14, respectively. The soil fertility status was medium in available nitrogen (290 and 282 kg ha^{-1}), high in available phosphorus (45 and 42 kg ha^{-1}) and high in available potassium (380 and 374 kg ha^{-1}), during 2012-13 and 2013-14, respectively.

The experiment was laid out in split plot design with five irrigation regimes (I_1-Continuous submergence of

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5±2; I_2-Rotational water supply of 5cm at 4 days on 3 days off ; I_3- Rotational water supply of 5 cm at 3 days on 2 days off; I_4- Rotational water supply of 3 cm at 2 days on 1day off; I_5-Continuous saturation) in main plots and five levels of weed management practices (W_1-Unweeded check; W_2-Weed-free check; W_3-Pretilachlor 50% EC on 1 DAT + hand weeding on 40 DAT; W_4-Bispyribac sodium 10% SC on 20 DAT + hand weeding on 40 DAT; W_5-Hand weeding twice on 20 and 40 DAT) in sub plots with three replications.

During the rice growing season, the daily ponded water depth was measured by water level indicators and recorded manually. Ponded water depth on the field in all experimental plots was kept between the 10 and 50 mm during first 14 days after transplanting in both seasons. Irrigation schedule was followed from the 15 DAT to 10 days before harvesting of the crop. The daily ponded water depth in each paddy plot was measured by water level indicators and recorded manually. Irrigation water use efficiency was calculated by the following formula

$$\text{Water use efficiency} = \frac{\text{Marketable grain yield (kg ha}^{-1})}{\text{Irrigation water applied (mm)}}$$

The sampling techniques for all the growth and yield characters including estimation of yield were followed as per standard procedures. For dry matter estimation, five plants were randomly selected from sampling area and they were cut at ground level at 30, 60, 90 DAT and at harvest. The samples were dried in shade and again oven dried at 70ºc, till a constant weight was obtained and the dry matter was expressed in g m^{-2}. The grain yield was recorded at 14% moisture content. Statistical analysis was done using the OP-STAT software developed by the CCSHAU, Haryana.

RESULTS AND DISCUSSION

Growth and development in plants are a consequence of excellent coordination of several processes operating at different growth stages. Irrigation treatments influenced the growth attributes of rice crop viz., plant height, number of tillers, plant DMA and LAI positively at all the stages of observation during both the years of experimentation and pooled data (Table 1, 2, 3 and 4). Growth attributes of rice crop were higher in first year (2012-13) of experimentation than the second year (2013-14). Irrespective of years of experimentation and different dates of recording observations the taller plants were produced in plots which were maintained with continuous submergence of 5±2 (I_1). Among the other levels of irrigation, significantly higher plant height in the plots receiving I_3 followed by I_2, I_4 and I_5 in pooled data except at 30 DAT. All the weed control measures, recorded significantly higher plant height compared to the weedy check (W_1) in different stages of observation in both the years and pooled data. All the weed control measures were at par with each other at harvest stage in both the years and pooled data (except W_4 treatment).

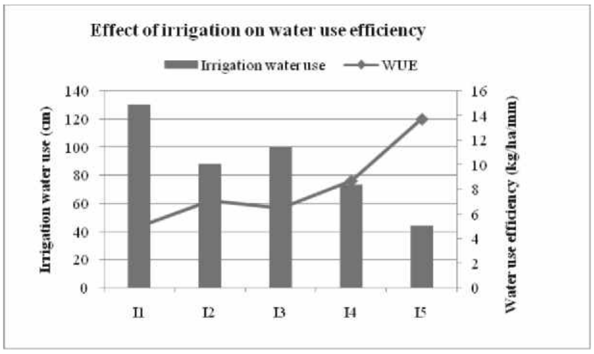

Fig.1 : **Effect of irrigation on water use and water use efficiency of lowland rice (Pooled data).**

Significantly higher total number of tillers (m^{-2}) was recorded in plots which were maintained with continuous submergence of 5±2 (I_1) followed by I_3, I_2, I_4 and I_5 in both the years and pooled data at different stages of observation (except at 30 DAT in 2012-13). The total number of tillers was highest at 60 DAT in all experimental plots. All the weed control measures were significantly influenced the total number of tillers (m^{-2}) compared to the weedy check (W_1) in different stages of observation in both the years and pooled data. Among the weed control measures, pretilachlor at 1 DAT + hand weeding at 40 DAT (W_3) recorded maximum number of tillers (m^{-2}) followed by W_5, W_4 and W_1 treatments at different stages of observation in both the years and pooled data.

The biological efficiency of any crop species depends on the amount of dry matter it produces. Amount of irrigation water applied showed positive response on the plant dry matter production, which was highest in plots which were maintained with continuous submergence of 5±2 (I_1) followed by I_3, I_2, I_4 and I_5 in both the years and pooled data at different stages of observation. Weed control measures were significantly influenced the plant dry matter production. Among the weed control measures, pretilachlor at 1 DAT + hand weeding at 40 DAT (W_3) recorded maximum plant dry matter production followed by W_5, W_4 and W_1 treatments at different stages of observation in both the years and pooled data. This is due to the all the weed control measures have shown reduction in weeds density and dry weight contributed to the higher growth attributes *viz.*, plant height, no. of tillers, LAI, biomass which

Table 1: Effect of different irrigation regimes and weed control practices on plant height (cm) of rice.

Treatments	30 DAT			60 DAT			90 DAT			Harvest		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Levels of irrigation												
I_1	35.88	34.81	35.34	77.65	76.11	76.88	94.04	90.28	92.16	99.49	95.24	97.37
I_2	35.02	33.97	34.49	75.56	74.05	74.80	91.71	88.04	89.88	97.42	93.91	95.67
I_3	35.27	34.23	34.75	76.39	74.86	75.62	92.28	88.51	90.40	98.16	94.40	96.28
I_4	35.08	33.89	34.49	75.35	73.54	74.44	91.04	87.24	89.14	96.49	92.91	94.70
I_5	34.22	33.28	33.75	73.36	72.06	72.71	88.58	85.28	86.93	95.73	92.08	93.90
SEm(±)	**0.120**	**0.005**	**0.061**	**0.267**	**0.254**	**0.093**	**0.33**	**0.26**	**0.155**	**0.333**	**0.35**	**0.128**
LSD (0.05)	**0.391**	**0.017**	**0.201**	**0.868**	**0.828**	**0.305**	**1.06**	**0.84**	**0.503**	**1.085**	**1.13**	**0.418**
Methods of weed control												
W_1	27.24	26.52	26.88	65.24	64.09	64.66	80.71	77.64	79.18	90.74	84.27	87.51
W_2	38.24	37.10	37.67	80.19	78.60	79.39	96.18	92.34	94.26	100.09	97.09	98.59
W_3	37.23	36.13	36.68	79.29	77.70	78.50	95.93	92.10	94.01	99.78	96.79	98.28
W_4	36.30	35.18	35.74	76.43	74.86	75.64	91.66	87.93	89.79	97.71	94.71	96.21
W_5	36.45	35.25	35.85	77.15	75.36	76.26	93.16	89.33	91.25	98.97	95.68	97.33
SEm(±)	**0.346**	**0.342**	**0.293**	**0.740**	**0.755**	**0.617**	**0.89**	**0.88**	**0.782**	**0.943**	**0.95**	**0.784**
LSD (0.05)	**0.988**	**0.979**	**0.839**	**2.116**	**2.159**	**1.763**	**2.55**	**2.53**	**2.235**	**2.696**	**2.73**	**2.24**

Note: Y_1*:2012-13;* Y_2*: 2013-14; Interaction effects are non-significant.*

Table 2: Effect of different irrigation regimes and weed control practices on number of tillers (m^{-2}) of rice.

Treatments	30 DAT			60 DAT			90 DAT			Harvest		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Levels of irrigation												
I_1	215.11	215.68	214.40	412.02	368.65	390.33	399.62	342.97	371.30	390.29	331.96	361.12
I_2	199.86	200.32	200.09	386.77	345.33	366.05	372.33	317.97	345.15	360.96	305.62	333.28
I_3	208.60	207.98	208.29	396.16	355.08	375.62	382.98	328.53	355.75	371.78	316.87	344.33
I_4	194.29	195.97	195.13	378.39	337.25	357.82	367.45	313.39	340.42	352.41	298.97	325.69
I_5	192.59	193.21	192.89	373.35	331.36	352.36	360.37	306.27	333.32	345.43	293.13	319.28
Sem(±)	**0.691**	**0.726**	**0.613**	**1.406**	**0.908**	**0.561**	**1.347**	**0.755**	**0.924**	**1.237**	**0.092**	**0.626**
LSD (0.05)	**2.249**	**2.364**	**1.997**	**4.578**	**2.956**	**1.827**	**4.388**	**2.458**	**3.009**	**4.029**	**0.301**	**2.039**
Methods of weed control												
W_1	150.53	179.19	164.86	245.72	243.31	244.52	233.71	232.09	232.90	224.39	228.42	226.40
W_2	235.13	225.78	230.45	451.34	396.12	423.73	437.72	365.87	401.79	426.12	351.96	389.04
W_3	221.30	213.66	217.48	439.55	386.06	412.80	426.33	356.33	391.33	414.52	341.89	378.20
W_4	197.61	192.93	195.27	400.34	352.28	376.31	385.49	321.98	353.74	371.81	307.10	339.46
W_5	205.88	199.60	202.74	409.73	359.91	384.82	399.50	332.86	366.18	384.02	317.18	350.60
Sem(±)	**2.000**	**2.045**	**1.753**	**3.962**	**3.584**	**2.962**	**3.840**	**3.250**	**3.070**	**3.774**	**3.248**	**3.034**
LSD (0.05)	**5.717**	**5.846**	**5.012**	**11.328**	**10.248**	**8.467**	**10.978**	**9.292**	**8.776**	**10.791**	**9.286**	**8.674**

Note: Y_1*:2012-13;* Y_2*: 2013-14; Interaction effects are non-significant.*

Table 3: Effect of different irrigation regimes and weed control practices on dry matter accumulation (g m^{-2}) of rice.

Treatments	30 DAT			60 DAT			90 DAT			Harvest		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Levels of irrigation												
I_1	377.65	343.65	360.66	653.23	607.48	630.37	1306.51	1226.21	1266.36	1457.18	1370.35	1413.76
I_2	346.29	315.12	330.71	586.19	545.15	565.68	1194.03	1118.83	1156.41	1353.35	1264.74	1309.04
I_3	359.89	327.52	343.70	619.75	575.57	597.65	1220.25	1149.39	1184.82	1405.52	1313.48	1359.49
I_4	338.93	308.57	323.76	571.75	531.75	551.74	1175.59	1101.51	1138.55	1317.36	1231.08	1274.21
I_5	328.93	299.32	314.12	549.75	509.31	529.39	1133.82	1078.40	1106.11	1286.49	1202.25	1244.38
Sem(±)	**1.257**	**0.929**	**0.849**	**2.354**	**1.272**	**1.320**	**4.432**	**2.626**	**3.206**	**4.616**	**3.133**	**1.913**
LSD (0.05)	**4.093**	**3.025**	**2.766**	**7.669**	**4.142**	**4.301**	**14.437**	**8.553**	**10.442**	**15.034**	**10.206**	**6.233**
Methods of weed control												
W_1	251.21	228.62	239.91	419.55	389.67	404.61	854.71	802.88	828.78	1021.25	962.39	991.81
W_2	400.93	364.85	382.90	689.39	641.14	665.28	1354.99	1269.64	1312.31	1523.01	1423.27	1473.84
W_3	390.75	355.70	373.22	659.13	612.99	636.06	1335.46	1251.31	1293.37	1492.71	1394.97	1443.84
W_4	348.14	316.82	332.47	600.44	558.07	579.25	1214.42	1157.91	1186.17	1378.65	1288.96	1333.78
W_5	360.66	328.20	344.44	611.90	567.37	589.63	1270.63	1192.59	1231.62	1404.28	1312.31	1358.29
Sem(±)	**3.594**	**3.248**	**2.813**	**6.023**	**5.611**	**4.084**	**12.386**	**11.512**	**10.534**	**13.978**	**12.888**	**11.462**
LSD (0.05)	**10.276**	**9.287**	**8.044**	**17.219**	**16.043**	**11.677**	**35.410**	**32.912**	**30.116**	**39.964**	**36.846**	**32.769**

Note: Y_1: 2012-13; Y_2: 2013-14; Interaction effects are non-significant.

Table 4: Effect of different irrigation regimes and weed control practices on LAI of rice.

Treatments	30 DAT			60 DAT			90 DAT			Harvest		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Levels of irrigation												
I_1	2.51	2.48	2.49	3.61	3.51	3.56	4.44	4.28	4.36	3.20	3.11	3.15
I_2	2.41	2.38	2.39	3.47	3.38	3.43	4.32	4.16	4.24	3.09	3.00	3.05
I_3	2.46	2.43	2.44	3.52	3.43	3.48	4.37	4.22	4.29	3.14	3.05	3.10
I_4	2.33	2.30	2.32	3.42	3.34	3.38	4.28	4.12	4.19	3.02	2.93	2.98
I_5	2.27	2.24	2.25	3.38	3.28	3.33	4.23	4.07	4.15	2.95	2.87	2.91
Sem(±)	**0.011**	**0.008**	**0.008**	**0.013**	**0.001**	**0.006**	**0.013**	**0.011**	**0.006**	**0.010**	**0.008**	**0.009**
LSD (0.05)	**0.035**	**0.024**	**0.025**	**0.041**	**0.003**	**0.020**	**0.043**	**0.035**	**0.018**	**0.034**	**0.027**	**0.029**
Methods of weed control												
W_1	2.27	2.24	2.25	2.71	2.64	2.67	3.45	3.32	3.38	2.50	2.43	2.46
W_2	2.53	2.50	2.52	3.83	3.72	3.77	4.76	4.59	4.68	3.31	3.21	3.26
W_3	2.48	2.44	2.46	3.72	3.62	3.67	4.64	4.76	4.56	3.23	3.14	3.19
W_4	2.34	2.31	2.32	3.55	3.46	3.50	4.35	4.19	4.27	3.16	3.07	3.17
W_5	2.36	2.33	2.35	3.60	3.51	3.56	4.44	4.28	4.36	3.20	3.11	3.15
Sem(±)	**0.024**	**0.024**	**0.021**	**0.035**	**0.034**	**0.028**	**0.045**	**0.042**	**0.035**	**0.031**	**0.030**	**0.009**
LSD (0.05)	**0.069**	**0.068**	**0.061**	**0.100**	**0.097**	**0.079**	**0.127**	**0.121**	**0.100**	**0.089**	**0.086**	**0.030**

Note: Y_1: 2012-13; Y_2: 2013-14; Interactioneffects are non-significant.

Table 5: Effect of different irrigation regimes and weed control practices on yield attributes and yield of rice.

Treatments	No. of panicles m^{-2}			Panicle length (cm)			Test weight (g)			Filled grains panicle^{-1}			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Levels of irrigation																		
I_1	356.14	318.27	337.21	24.38	24.11	24.25	17.57	17.41	17.49	128.03	123.52	125.77	7062	5859	6471	8560	7122	7841
I_2	328.32	292.34	310.33	24.00	23.74	23.87	17.42	17.25	17.34	125.21	120.97	123.09	6769	5642	6206	8247	6879	7563
I_3	334.28	300.91	317.59	24.13	23.87	24.00	17.45	17.28	17.37	126.45	121.44	123.95	6926	5770	6348	8318	6938	7628
I_4	320.47	284.90	302.69	23.89	23.63	23.76	17.37	17.22	17.30	124.22	119.80	122.01	6615	5519	6067	8112	6767	7439
I_5	311.85	278.70	295.28	23.73	23.47	23.60	17.43	17.26	17.35	123.15	119.20	121.18	6517	5414	5965	7962	6682	7322
SEm(±)	**0.717**	**0.734**	**0.477**	**0.095**	**0.002**	**0.047**	**0.084**	**0.006**	**0.045**	**0.022**	**0.017**	**0.021**	**2.22**	**13.29**	**7.14**	**2.31**	**20.51**	**10.55**
LSD (0.05)	**2.336**	**2.390**	**1.555**	**0.305**	**0.006**	**0.153**	**0.152**	**0.014**	**0.087**	**0.071**	**0.055**	**0.067**	**7.23**	**43.30**	**23.25**	**7.53**	**66.80**	**34.38**
Methods of weed control																		
W_1	220.99	226.31	223.65	23.08	22.83	22.95	17.18	17.13	17.16	118.13	114.13	116.13	4224	4195	4210	7303	6272	6787
W_2	381.10	334.99	358.04	24.70	24.43	24.56	17.60	17.42	17.51	128.37	123.95	126.16	7841	6351	7096	8906	7392	8149
W_3	371.49	325.36	348.43	24.55	24.28	24.42	17.52	17.33	17.43	127.41	123.11	125.26	7668	6211	6939	8676	7184	7930
W_4	332.02	290.00	311.01	23.84	23.58	23.71	17.40	17.21	17.31	126.49	121.80	124.14	7039	5701	6370	8121	6740	7430
W_5	345.47	298.47	321.97	23.97	23.71	23.84	17.43	17.24	17.34	126.66	121.95	124.31	7118	5765	6442	8193	6800	7497
Sem(±)	**3.348**	**2.965**	**2.896**	**0.240**	**0.236**	**0.207**	**0.189**	**0.154**	**0.167**	**1.251**	**1.207**	**1.229**	**68**	**57**	**60**	**81**	**68**	**71**
LSD (0.05)	**9.572**	**8.476**	**8.278**	**0.687**	**0.675**	**0.593**	**0.458**	**0.326**	**0.391**	**3.577**	**3.450**	**3.513**	**196**	**162**	**172**	**233**	**197**	**205**

Note: Y_1: 2012-13; Y_2: 2013-14; Interaction effects are non-significant.

ultimately resulted in yield of rice crop. Similar results were also opined by the Rashid, *et al*. (2012).

Significantly higher LAI recorded in plots with application of continuous submergence of 5±2 (I_1) followed by I_3, I_2, I_4 and I_5 in both the years and pooled data at different stages of observation (except at 60 DAT where I_4 and I_5 treatments were comparable with each other in 2012-13). All the weed control measures were significantly influenced the LAI compared to the weedy check (W_1) in different stages of observation in both the years and pooled data. Among the weed control measures, weed free check (W_2) was comparable with the pretilachlor at 1 DAT + hand weeding at 40 DAT (W_3) at 30, 90 and harvest stages of observation in both the years followed by W_5 and W_4 which were comparable at all different stages of observation in both the years and pooled data.

Yield attributes and yield

The experimental results revealed that yield attributing parameters *viz.*, number of panicles (m^{-2}), panicle length (cm), filled grains (No.), and yield (kg ha^{-1}) were significantly higher in continuous submergence of 5±2 (I_1) treatment compared to all other irrigation treatments (Table 5). Continuous saturation treatment (I_5) gives just 7.82% less grain yield (pooled of 2 yrs) than the continuous submergence of 5±2 (I_1) treatment. Similar results were found by the Tabbal *et al.* (2002); Bouman and Tuong (2001). Shao *et al.* (2014) found that with wetting and drying cycles, controlled irrigation and drainage (CID) strengthens the air exchange between soil and the atmosphere, thus sufficient oxygen is supplied to the root system to accelerate soil organic matter mineralization, all of which should produce more essential land available nutrients to favour rice growth. This might be the reason for satisfactory yields recorded in continuous saturation treatment. Whereas, among the weed management practices, weed-free check followed by W_3, W_5 and W_4 gave significantly higher yield attributing characters and yield compared to the weedy check (W_1).

Water saving and water use efficiency

The irrigation water used under the different irrigation treatments was highest (130.3 cm) in continuous submergence treatment followed by the I_3, I_2, I_4 and I_5. Water use efficiency is computed based on the grain yield (kg ha^{-1}) devided by the total irrigation water (mm) applied indicated that lower water use efficiency was recorded in continuous submergence as compared to other irrigation treatments (Fig.1). Whereas, significantly higher water use efficiency (13.7 kg ha^{-1} mm^{-1}) was recorded in continuous saturation due to lower application of irrigation water than the continuous submergence (5.0 kg ha^{-1} mm^{-1}). Bouman and Tuong (2001) revealed that large reductions in water input can potentially be realized by reducing the unproductive seepage, percolation flows during crop growth and idle periods.

From the experiment it is concluded that continuous saturation moisture regime in boro rice crop of lowland field's gives satisfactorily good yields (7.28% less than the continuous submergence 5±2 cm depth of water) with water use efficiency 13.7 kg ha^{-1} mm^{-1}.

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