IJTA © Serials Publications
National Academy of Agricultural Science (NAAS) Rating : 3. 03

Response of Rain-fed Rice to Supplemental Irrigation with Drip and Surface Irrigation Methods in Eastern India

P. Panigrahi*, S. K. Rautaray, R. K. Panda, A.K. Thakur and S. Raichaudhuri

Abstract: *Longer duration and higher frequency of dry spells in monsoon season is one of the major causes of low productivity and failure of rice crops in India. Keeping this in view, a field experiment was conducted to study the response of kharif rice to supplemental irrigation under drip and surface irrigation methods in a sub-humid tropical climate of eastern India. Water was applied to rice after three days of drainage of standing water in field. Different drip irrigation (DI) treatments imposed were irrigation at 125% crop evapo-transpiration (ET_c), 100% ET_c and 75% ET_c, at 1.0 m lateral layout (lateral-to-lateral distances) whereas surface irrigation (SI) was applied through flexible hose-pipe to rice plots. Rain-fed rice was taken as control treatment for comparison. The irrigation water applied under different DI treatments varied from 108 mm to 179 mm whereas it was 250 mm under SI. The highest vegetative growth of rice was recorded under DI at 125% ET_c, whereas higher grain yield was harvested from SI which was statistically at par with that under DI at 100% ET_c and 125% ET_c. However, the maximum irrigation water use efficiency was obtained from DI at 100% ET_c. The grain yield of drip-irrigated rice was 26% higher than rain-fed rice. The effect of irrigation on available nutrients (N, P and K) in soil was statically ($p>0.05$) insignificant.*

INTRODUCTION

India is the second largest producer of paddy rice (157.8 million tonnes) after China, accounting for 20% of world rice production. Rice is predominantly grown in low and medium lands as a rain-fed crop during monsoon season (July–October) under humid and sub-humid regions of India. Eastern India has the largest area under rainfed rice, due to adequate rainfall (>1200 mm) during crop season (*kharif*) in this region. However, the productivity of rainfed rice in eastern India is very low (0.5–1.6 t ha^{-1}) compared with that in other parts of the country (Adhya *et al.*, 2008). Water scarcity caused by dry spells in critical growth stages of the crop during monsoon season is one of the major reasons for sub-optimal productivity of rainfed rice. Providing supplemental irrigation during dry spells could enhance the productivity of rice during rainy season.

The water availability in eastern India is not a constraint. However, the accessibility to water is very low in this region. The undulating topography in conjunction with geological and hydrological constraints restricts the water supply through canal irrigation and tubewell irrigation in this region. Rainwater harvesting and its efficient use has been found as a potential option to enhance productivity of rice in eastern India (Srivastava and Panda, 1998). Moreover, in water scarce environment, higher water productivity is an important indicator for sustainable agriculture. The use of water saving techniques is one of the options to enhance water productivity in any crop. As rainwater harvesting in tanks is cost effective, use of harvested water through efficient ways is essential in rice cultivation.

The past studies indicated that alternative wetting and drying (AWD) is a potential water saving practice in rice cultivation (Bouman and Toung, 2001). Under AWD, the rice field is allowed to dry for a few days between irrigation events, including a mid season drainage in which the field is allowed to dry for 7-15 days at the end of the tillering stage. This technique has the potential to improve the productivity of rice under saturated soil conditions with substantially water saving compared with continuous flood irrigation. Borell *et al.* (1997) reported that rice grown on raised beds under saturated soil condition reduced

ICAR-Indian Institute of Water Management, Bhubaneswar-751023, Odisha, India
**E.mail: pravukalyan.panigrahi@gmail.com; pravukalyan@rediffmail.com*

the amount of water use by 32% over conventional methods. Drying for short duration at the end of the tillering stage and just before flowering followed by flooding improved the yield of wetland rice with reduced water supply (Neue, 1993).

Drip irrigation has been found as a potential water saving technique in horticultural crops. However, the information on the response of rice to drip irrigation is scanty. Keeping this in view, an experiment was conducted to study the comparative performance of drip and surface irrigation as supplemental irrigation in *kharif* rice in eastern India.

MATERIALS AND METHODS

The field experiment was conducted during July–October 2013 to study the response of *kharif* rice (Variety 'Khandagiri') to drip irrigation (DI) and surface irrigation (SI) at Deras Research Farm, Mendhasal of ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha. The plants were transplanted with plant to plant and row to row spacing of 15 cm and 20 cm, respectively. Two lateral layouts were tried with lateral to lateral spacing of 1.4 m and 1.0 m with four DI regimes. DI imposed were at 125% crop water requirement (ET_c), 100% ET_c and 75% ET_c. The SI was scheduled after 3 days of drainage of surface water and rain-fed rice was taken as control treatment for comparison.

The experimental soil is sandy loam (45% sand, 24% silt and 31% clay) with bulk density of 1.44 g cm^{-3}. The field capacity and permanent wilting point were 0.17–0.31 cm^3/cm^3 and 0.05-0.12 cm^3/cm^3, respectively. The experimental soil is acidic (pH, 5.91) in nature. The hydraulic performance of the drip system was found satisfactory with emitter flow rate variation (Q_v) of 8%, co-efficient of variation (CV) of 6% and distribution uniformity (DU) of 94%. The groundwater was present at 8 m depth from land surface of the experimental site.

The climate of the study site is sub-tropical in nature with hot-humid summers. The hottest months of the year are May and June with maximum daily temperature of 44 ^{0}C, whereas January is the coldest month with mean temperature of 12 ^{0}C. The mean annual rainfall of the site is 1500 mm, out of which around 85% takes place during June-September.

The intermittent water supply was performed as supplemental irrigation from July to Mid-November of the experimental year. Irrigation was initiated through both DI and SI after three days of drainage of standing water from rice field. The experiment was laid out in split plot design with irrigation as main-plot treatment and lateral layout as sub-plot treatments. Each treatment plot size was 8 m x 7 m. The irrigation water quantity under DI was estimated using the formula, $ET_c = \{(E_p \times K_p \times K_c) - ER\}/ (IE)$, where ET_c is the crop evapotranspiration (mm day^{-1}); E_p the pan evaporation rate (mm day^{-1}); K_p the pan evaporation co-efficient; K_c the crop coefficient; ER, Effective rainfall (mm day^{-1}) and IE the irrigation efficiency (90%) of drip system. Under SI, 5 cm water was applied each time through hose pipe. The effective rainfall during the experiment was worked out following the procedure suggested by FAO-25 (Dastane, 1978). The volume of water (l day^{-1}) applied was calculated by multiplying ET_c with crop area (m^2) under DI, whereas in SI the volume of water applied each time was calculated by multiplying irrigation depth (5 cm) with crop area.

The amount of water required for different irrigation treatments was regulated by adjusting the operating hours of the irrigation system from time to time. The flow of water in lateral pipes was controlled by lateral valves provided at the inlet end of the pipes. The application of NK-based fertilizers under DI was performed through irrigation water whereas P was applied through soil. Under SI, NPK fertilizers were applied manually as per recommendation. Intercultural operation and the plant protection measures against insect pests and diseases were adopted uniformly for all treatments as per the recommendations given for the crop in the region.

The soils samples at 0-30 cm, 30-60 cm and 60-90 cm depths from 10 cm, 20 cm, 30 cm and 40 cm distances from lateral pipes were collected and analyzed for available macronutrients (N, P and K) following standard procedures. The depth wise pulled data was estimated. The vegetative growth of plants (plant height and number of tillers), yield parameters (grain per panicle, weight per 1000 grains, grain yield and straw yield) were recorded from time to time and irrigation water productivity (IWP) was estimated by calculating yield per unit quantity of water used. The data generated were subjected to analysis of variance (ANOVA) and critical difference (CD) at 5% level was obtained using the methods described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The pattern of rainfall, pan evaporation and irrigation in rice during cropping season is presented in Figure 1. The dry spells occurred during 16 days after transplanting (DAT) –32 DAT and 55 DAT–64 DAT. DI was operated for 13 days whereas 5 number of

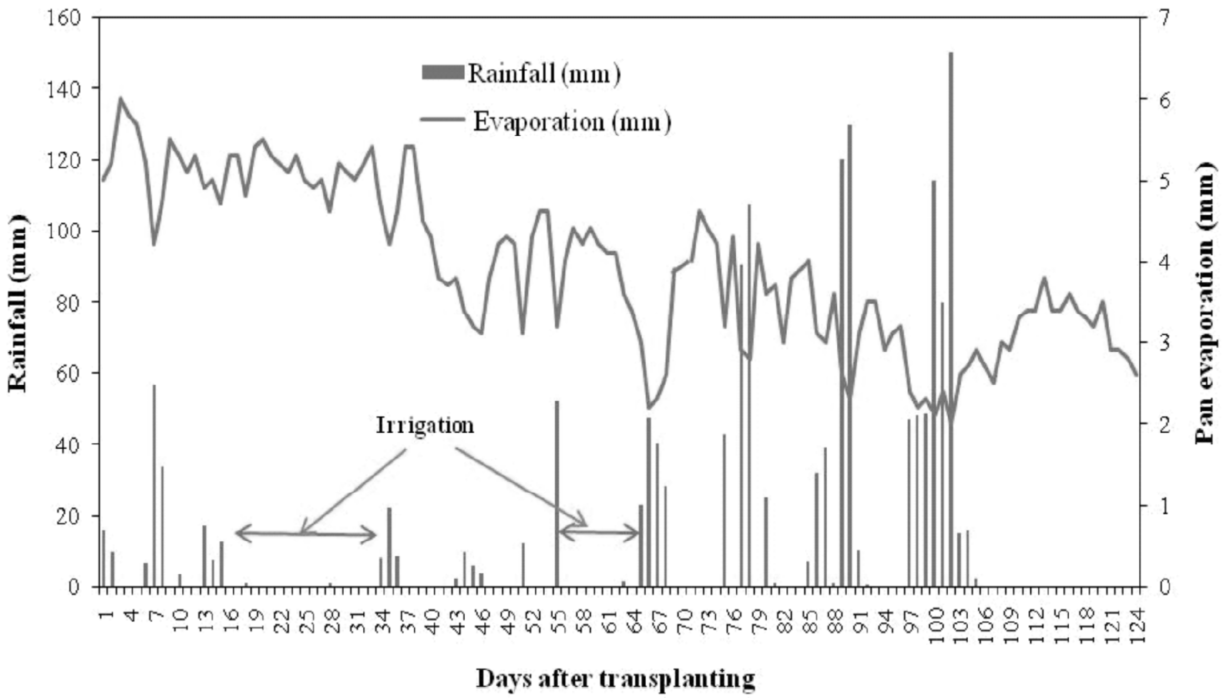

Figure 1: Pattern of rainfall and irrigation for *kharif* rice during 2013

supplemental irrigation was applied with SI (Table 1). The amount water applied under DI at 125% ET_c, 100% ET_c and 75% ET_c were 179 mm, 144 mm and 108 mm, respectively, whereas 250 mm water was applied under SI. The reduction in water supply through DI was due to less evaporation, seepage and percolation under this system compared to SI (Panigrahi *et al.,* 2012). The soil water content (SWC) observed at 30 cm depth during irrigation period indicates that the higher level of irrigation under DI resulted in significantly higher SWC compared to other treatments. The highest fluctuation in SWC was observed with SI compared to DI due to maximum water loss through evapotranspiration coupled with higher seepage and percolation losses from soil under SI. The higher SWC depletion under SI over DI was due to increased water extraction rate by plants with SI (Cohen, 2001).

The available N, P and K concentration in the soil improved under different irrigation treatments (Table 2). The improvement in N, P and K was due the application of NPK-based fertilizers during crop season. The maximum increase in available nutrients was observed under DI at 125% ET_c, whereas the minimum was observed with rainfed treatment. Moreover, the decrease in incremental available nutrients was observed with decrease in irrigation regime under DI. The higher availability of nutrients might be due to increased soil water content in this treatment which induced better microbial activities in *rhizosphere* of the crop. The lower lateral to lateral distances (1.0 m) induced higher available N, P and K in soil. However, the incremental in available N, P and K was not affected significantly due to irrigation. The annual increase in available nutrients under the treatments suggests for reduction in fertilizer application under DI.

The vegetative growth parameters of the plants (plant height, EBT per till) were significantly affected by irrigation treatments and lateral layouts (Table 3). The highest growth of the plants was observed with SI, followed by DI_{125}. The higher plant growth was observed with higher level of irrigation under DI. The higher vegetative growth under higher level of irrigation was probably due to higher photosynthesis rate and its proportionate partitioning towards vegetative growth under this treatment. Previously, Panigrahi *et al.* (2012) showed the similar findings of

Table 1
Irrigation water applied (mm) under different irrigation treatments in rice

Treatments	*Number/ Days of irrigation*	*Water applied (mm)*
Drip irrigation at 125% ET_c	13	179
Drip irrigation at 100% ET_c	13	144
Drip irrigation at 75% ET_c	13	108
Surface irrigation	5	250
Rainfed	–-	–-

Table 2
Changes in available N, P and K (mg kg^{-1} soil) in soil under different irrigation treatments in rice

Treatments		*0–30 cm*			*30–60 cm*			*60–90 cm*		
		N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
DI_{125}	L_1	+2.71	+0.83	+4.11	+1.68	+0.56	+2.23	+1.13	+0.34	+2.17
	L_2	+2.82	+0.85	+4.25	+1.77	+0.61	+2.71	+1.17	+0.45	+2.21
DI_{100}	L_1	+2.64	+0.75	+3.85	+1.66	+0.49	+2.14	+0.96	+0.29	+2.03
	L_2	+2.75	+0.78	+4.01	+1.72	+0.43	+2.59	+1.12	+0.33	+2.11
DI_{75}	L_1	+2.26	+0.61	+3.66	+1.24	+0.38	+2.06	+0.84	+0.22	+1.93
	L_2	+2.35	+0.68	+3.67	+1.37	+0.34	+2.47	+0.77	+0.26	+1.99
SI		+2.10	+0.95	+3.25	+1.29	+0.30	+1.84	+1.49	+0.51	+2.33
Rainfed		+1.92	+0.65	+2.95	+1.17	+0.22	+1.47	0.66	+0.23	+1.26
$CD_{0.05}$	I	0.21	ns	0.13	ns	ns	ns	0.05	ns	0.22
	L	ns	ns	ns	ns	ns	ns	ns	ns	ns
	IxL	0.08	ns	0.06	ns	ns	ns	0.03	ns	0.13

DI_{125}: Drip irrigation at 125% ETc, DI_{100}: Drip irrigation at 100% ETc, DI_{75}: Drip irrigation at 75% ETc, SI: Surface irrigation, L_1: 1.4 m lateral distance; L_2: 1.0 m lateral distance

Table 3
Vegetative growth, yield and IWUE of *kharif* rice under drip and surface irrigation methods

Treatments		*Plant height (cm)*	*EBT/ till*	*Grain per penicle*	*Grain weight per 1000 grains (g)*	*Grain yield (t /ha)*	*straw yield (t /ha)*	*Water applied (m^3/ha)*	*IWUE (kg/m^3)*
DI_{125}	L_1	94.6	11.8	61.8	22.8	4.19	5.21	1790	0.441
	L_2	95.1	12.1	62.1	23.0	4.39	5.46	1790	0.553
DI_{100}	L_1	92.8	11.4	61.4	22.7	4.01	5.04	1440	0.423
	L_2	93.2	11.8	61.7	22.9	4.27	5.13	1440	0.604
DI_{75}	L_1	91.7	11.0	60.9	22.4	3.87	4.69	1080	0.435
	L_2	92.1	11.2	61.3	22.7	3.92	4.87	1080	0.482
SI	95.6	12.7	62.4	23.2	4.48	5.83	2500	0.432	
Rainfed		89.2	9.4	57.8	20.6	3.40	4.11	–	–-
$CD_{0.05}$	I	4.1	2.7	11.5	3.6	0.7	0.3	21	–-
	L	3.7	1.8	6.4	2.9	0.8	0.5	16	–-
	IxL	4.6	3.1	9.8	4.7	0.5	0.8	22	

DI_{125}: Drip irrigation at 125% ET_c, DI_{100}: Drip irrigation at 100% ET_c, DI_{75}: Drip irrigation at 75% ET_c, SI: Surface irrigation, L_1: 1.4 m lateral distance; L_2: 1.0 m lateral distance

decrease in vegetative growth of deficit-irrigated plants. The minimum growth of the plants was observed in rainfed treatment. Moreover, the growth parameters were higher with lower lateral to lateral distance with corresponding irrigation regime.

The yield parameters (grain per panicle, grain weight per 1000 grains, grain yield and straw yield) in various irrigation treatments are presented in Table 2. The yield parameters were recorded to be higher under SI, followed by DI at 125% ET_c. The lower level of DI resulted in lower yield. The more yield with SI might be due to lower weed infestation in this treatment. However, the yield in SI was statistically at par with that under DI at 100% ET_c and 125% ET_c. The grain yield under DI was 26% higher than rain-fed rice. The highest IWP was observed under DI_{100}, followed by DI_{125}. The lowest IWP was in SI. The higher IWP resulted in DI_{100} was due to higher increase in fruit yield with comparatively less increase in irrigation water applied under this treatment over other treatments.

CONCLUSIONS

The changes in available N, P and K in soil were affected insignificantly under irrigation treatments. The higher vegetative growth with maximum grain yield was recorded with surface-irrigated rice. However, grain yield in DI_{125} and DI_{100} was statistically at par with that in surface irrigation. With 42% less irrigation water use, DI_{100} with 1.0 m lateral spacing resulted 40% higher IWP compared with surface irrigation. Thus, drip irrigation at 100% ET_c with 1.0 m lateral to lateral distance may be used for supplemented irrigation in *kharif* rice in eastern India.

REFERENCES

Adhya, T. K., Singh, O. N., Swain, P. and Ghosh, A. (2008), Rice in eastern India: causes for low productivity and available options. *Journal of Rice Research*, 2 (1): 1–5.

Borell, A. K., Garside, A. and Fukai, S. (1997), Improving efficiency of water use for irrigated rice in a semi-arid tropical environment. *Field Crop Research*, 52: 231–2 48.

Bouman, B.A.M. and Tuong, T.P. (2001), Field water management to save water and increase its productivity in irrigated rice. *Agricultural Water Management*, 49: 11–30.

Cohen, M. (2001), Drip irrigation in lemon orchards. *International Water and Irrigation*, 21(1): 18–21.

Dastana, B. F. (1978), Effective rainfall. FAO Irrigation and Drainage Paper 35, FAO, Rome, Italy.

Gomez, K. A. and Gomez, A. A. (1984), Statistical Procedures for Agricultural Research, John Wiley and Sons, New York.

Neue, H. (1993), Methane emission from rice fields: Wetland rice fields may make a major contribution to global warming. *Bio Science*, 43 (7): 466 – 473.

Panigrahi, P., Srivastava, A. K. and Huchche, A. D. (2012), Effects of drip irrigation regimes and basin irrigation on Nagpur mandarin agronomical and physiological performance. *Agricultural Water Management*, 104: 79–88.

Srivastava, R.C., Panda, R.K. (1998), Potential and prospects of runoff recycling based irrigation system in plateau region of eastern India. *Indian Journal of Soil Conservation*, 26 (2): 104–108.