Indian Journal of Agronomy **52** (2) : 102–106 (June 2007)

Influence of irrigation regime and nitrogen management on productivity, nitrogen uptake and water use by rice (*Oryza sativa*)

Y. RAMAKRISHNA, SUBEDAR SINGH* AND S.S. PARIHAR

Water Technology Centre, Indian Agricultural Research Institute, New Delhi 110 012

Received : November, 2006

ABSTRACT

A field experiment was conducted on deep sandy clay-loam soil (Typic Haplustepts) at New Delhi, during 2002 and 2003 to investigate the effect of irrigation regimes, viz. continuous submergence, 1-day drainage, and 3-day drainage, and integrated nutrient management, viz. the control, 75% N of recommended fertilizer dose (RFD), 100% N of RFD, 150% of RFD, 75% N of RFD out of which 25% N substituted by farmyard manure (FYM), 100% N of RFD out of which 25% N substituted by FYM, 150% N of RFD of which 25% substituted by FYM and 75% N of RFD + biofertilizer, on the productivity of rice (cv. 'Pusa Sugandh 3'). Continuous water submergence increased the maximum plant height, number of tillers, leaf-area index (LAI), dry-matter accumulation, number of panicles, grains/panicle, panicle length, 1,000-grain weight, and the grain and straw yields, which were statistically superior to 3-day drainage but on a par with those of 1-day drainage. Continuous water submergence resulted in 9.6–17.4% higher grain yield than 3-day drainage and 2.7-4.6% higher than 1-day drainage. Irrigation and water requirement of rice were higher with continuous submergence, whereas irrigation, use efficiency and field water-use efficiency were higher with 3-day drainage. Among the nitrogen treatments, application of 150% N of RFD (25% substituted by FYM) induced the highest growth and yield attributes over other treatments and outyielded 75% N of RFD by giving 21.7%, 75% N of RFD (25% substituted by FYM) by 17.1%, and 75% N of RFD + biofertilizer by 14.1% and 40.4% more grain yield than the control in the first year and 19.8%, 19.9%, 12.7% and 42.0% in record year. Highest N uptake was recorded with 150% of N of RFD (25% N substituted by FYM) in biomass. Agronomic-nitrogen efficiency was maximum with 1-day drainage and 100 kg N/ha applied through fertilizer. Irrigation-use efficiency and field water-use efficiency were higher with 150% N of RFD (25% N of RFD substituted by FYM). It was concluded that under less availability of water, irrigation may be applied on the basis of 1-day drainage with 150% N of RFD (25% substituted by FYM).

Key words : Continuous submergence, Drainage, Integrated nitrogen management, N uptake, Water requirement

Rice (*Oryza sativa* L.) is the major cereal crop in India, cultivated on 45 million ha and contributing 84 million tonnes grain production (Governmemt of India, New Delhi, 2005). It is an input-intenive crop, grown on 40 per cent of the total gross cultivated area. Its water requirement is quite high, which is met through ground-water and canal for its production, which leads to various problems of ground-water depletion, salinization etc. Irrigation plays a pivotal role in increasing the productivity of rice, though the efficiency and productivity of water are very low due to percolation losses and higher water requirement. Nitrogen plays an important role in increasing the yield of rice, but its efficiency is only 30-40% due to loss by runoff, leaching, ammonia volatilization and denitrification (Prasad, 1998). The use of organic N substitution plays an important role in increasing the N-use efficiency. Most of the Indian soils are low in N and to achieve a better yield, farmers generally apply a large quantity of inorganic N. Keeping this in view, an experiment was carried out to study the effects of different water regimes and integrated N application on growth, productivity, N uptake and water use by rice.

MATERIALS AND METHODS

A field experiment was conducted at Indian Agriculture Research Institute, New Delhi, during rainy (*kharif*) season of 2002 and 2003. The soil was sandy clay-loam in the top soil (0-15 cm) and loamy in the lower layers (15–90 cm), with field capacity 19–20% (w/w) and permanent wilting point 7–11% (w/w). It had pH 7.77, organic C (0.68–0.79%), available N (159–163 kg/ha), P (13.5–14 kg/ha) and K (296 – 300 kg/ha) in the 0-15 cm soil layer. The treatments comprised three irrigation regimes, viz.

***Corresponding author** (Email: ss_wtc@iari.res.in)

continuous water submergence, 1-day drainage and 3-day drainage in the main plots, and eight nitrogen treatments, viz. the control, 75% N of recommended fertilizer dose (RFD), 100% N of RFD, 150% N of RFD, 75% N of RFD (25% N substituted by farmyard manure: FYM), 100% N of RFD (25% N substituted by FYM), 150% N of RFD (25% N substituted by FYM) and 75% N of RFD + biofertilizer in the sub-plot split-plot design with three replications. Recommended dose of N was considered as 120 kg/ha. The rice crop cv. 'Pusa Sugandh 3' was transplanted on 25 July 2002 and 28 July 2003 at spacing of 20 cm × 15 cm. A uniform dose of 33 kg P/ha through single superphosphate and 37.35 kg K/ha through muriate of potash as well as half the nitrogen through urea as per the treatment was applied basal, whereas the remaining dose of nitrogen was applied in two equal parts as top-dressing at tillering and panicle-initiation stages of rice. The quantity of well-decomposed farmyard manure (FYM) containing 0.5 per cent N on dry-weight basis was calculated and incorporated in the soil before transplanting as per treatments. A measured quantity of water through 7.62 cm Parshall flume was applied at the rate of 40 mm in each irrgation as per treatments. The number of irrigations were 30 and 27 in continuous submergence, 21 and 17 in 1-day drainage, and 15 and 14 in 3-day drainage during 2002 and 2003, respectively. During the crop period, a total rainfall of 270.1 mm and 343.5 mm was received during the first and second year, respectively. In 2003 higher amount and well-distributed rainfall in August-September during vegetative stage decreased the irrigation demand of the crop. Agronomic N use (ANU) was calculated by the formula of Novoa and Loomis (1981).

RESULTS AND DISCUSSION

Water regime

Maximum plant height was observed with continuous submergence, which was significantly superior under 3-day drainage but on a par with that under 1-day drainage during both the years (Table 1). Continuous submergence recorded higher number of tillers than 1-day drainage, followed by 3-day drainage, but the differences were statistically non-significant. The rice plant is water-loving and performs better in continuous submergence than in 3-day drainage. The stress due to drainage led to lower plant height and tillers/hill. Submergence of water induces rapid elongation of internodes. On an average, the growth parameters were better in 2003 due to lower temperature and good rainfall at vegetative stage of rice.

Continuous submergence registered higher number of panicles/hill (14.3 - 11.7%), grains/panicle (5.6 - 3.3 %) and panicle length (3.6 - 3.5%) over 3-day drainage (Table 1). It provided a better conducive rhizosphere condition for better uptake of nutrients and in turn helped the plants to boost their growth, leading to the development of yield attributes through supply of more photosynthates towards the reproductive sink. Stress during the reproductive phase

Table 1. Influence of irrigation and nitrogen management on growth and yield attributes of rice at harvest

Treatment	Plant height (cm)		Tillers/hill		Panicles/hill		Panicle length (cm)		No. of grains/panicle		Test weight (g)	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Irrigation regime												
Continuous submergence	96.8	99.0	14.3	14.5	10.4	10.5	25.9	26.4	135.6	139.4	22.27	23.33
1-day drainage	94.8	96.9	13.3	13.8	9.7	10.1	25.5	26.0	133.7	136.5	21.66	23.13
3-day drainage	91.6	95.3	12.4	13.0	9.1	9.4	25.0	25.5	128.4	134.9	21.39	22.95
SEm ±	0.8	0.7	0.6	0.6	0.3	0.2	0.2	0.2	1.7	1.0	0.24	0.14
CD (P=0.05)	3.0	2.8	NS	NS	1.1	0.7	0.8	0.8	6.5	4.0	0.93	0.53
N regime												
Control	88.4	90.4	8.4	7.5	6.5	5.8	22.7	23.2	115.5	119.9	18.85	21.54
75% N of RFD	94.0	94.7	10.2	10.5	7.3	7.5	24.8	25.3	119.7	123.1	21.92	22.89
100% N of RFD	95.8	98.5	15.7	16.1	11.5	11.8	26.2	26.7	139.0	143.6	22.50	23.46
150% N of RFD	98.6	101.0	16.8	17.3	12.0	12.1	26.7	27.2	141.2	145.5	22.26	23.62
75% N of RFD (25% FYM)	92.4	94.7	10.4	11.5	7.5	8.3	24.8	25.3	130.8	135.1	21.81	23.01
100% N of RFD (25% FYM)	95.3	97.8	14.2	14.9	10.2	10.9	25.6	26.1	133.1	141.0	22.17	23.38
150% N of RFD (25% FYM)	98.7	102.7	17.0	17.2	12.6	12.8	27.4	28.0	144.6	150.0	22.83	23.75
75% N of RFD + biofertilizer	92.0	96.8	14.0	14.6	10.4	10.7	25.5	26.0	136.5	137.3	21.85	23.42
SEm±	2.1	1.8	1.4	1.4	0.9	0.7	0.7	0.8	3.6	2.7	0.81	0.36
CD (P=0.05)	6.0	5.2	4.0	4.0	2.6	1.9	2.0	2.2	12.7	9.3	2.32	1.03

might have hampered the supply of photosynthesatis towards the sink resulting in poor yield attributes. Stress due to water decreased the panicle production, whereas stress during the post-panicle initiation reduced the spikelets/panicle and during late stage reduced the grain filling, resulting in increased unfilled grain percentage and reduced test weight (Timsina *et al.,* 1998). The irrigation regimes of 1-day drainage and 3-day drainage probably caused stress to rice plant, resulting in reduced number of panicles/hill, panicle length, number of fertile grains/panicle and test weight. Jayaprakash and Wahab (1995) also reported similar findings.

Continuous water submergence gave the highest grain yield (4.69 and 4.89 t/ha), which was 9.55-17.38% more than under 3-day drainage, and 4.61 and 2.73% more than under 1-day drainage (Table 2). The yield attributes played direct role in grain yield. It is in conformity with the results of Pathak *et al.* (2003). Among the irrgation levels, continuous submergence gave maximum straw yield, which was significantly higher than under 3-day drainage but on a par with that under 1-day drainage.

Nitrogen regime

The rice plants fertilized with 150% RFD of N (25% N substituted by FYM) were the tallest (98.7 - 102.7 cm), with the highest number of tillers/hill (17.0 - 17.2) compared with the shortest height (88.4 - 90.4 cm) and minimum tillers/hill (8.4-7.5) with the control (Table 1). Nitrogen plays an important role in the cell growth and developments of the rice plant (Dar *et al.,* 2000).

Application of 150% N of RFD (25% substituted by FYM) resulted in maximum panicles/hill, panicle length, grains/panicle than the control (Table 1). Application of 150% RFD of N (25% substituted by FYM) probably fulfilled the N demand of rice through integration of inorganic and organic sources. Besides, FYM might have supplied the minerals and hormones and worked as catalyst for increasing the yield attributes. These findings are in close conformity with those of Sharma and Sharma (2002). Higher N application caused better N uptake leading to greater dry-matter production and its translocation towards sink (Dar *et al.,* 2000).

Application of 150% N of RFD (25% N substituted by FYM) outyielded 75% N of RFD by producing 21.7 and 19.8%, 75% N of RFD (25% N substituted by FYM) by 17.1, and 19.9% and the control by 40.4-42.0% more grain yield during the first and second year, respectively (Table 2). Farmyard manure (FYM) substitution for N might have provided more essential plant nutrients besides N in a balanced manner, which in turn helped the plant perform better than with 150% N of RFD in the form of inorganic N.

The interactive effects of irrigations and N on grain yield were significantly more with 150% N of RFD (25% substituted by FYM) under continuous submergence of water over 75% N of RFD and control at the same irrigation. Similarly, 150% N of RFD (25% substituted by FYM) performed better with other irrigation regimes also (Table 2). Application of organic N through FYM released N slowly to the plants and improved the soil health for better availability of nutrients (Ikeda and Watanabe, 2002). Higher concentration of N in rhizosphere led to higher N uptake by the plant biomass. Rice plant prefers NH_4^+-N at early stage of the crop growth, which is higher under continuous submergence, probably due to the slow rate of nitrification prevailing under oxygen-stress condition (Manguiat *et al.,* 1994).

Table 2. Effect of irrigation and integrated nitrogen management on grain yield (t/ha) of rice

Nitrogen regime	2002				2003			
	Continuous water submergence	1-day drainage	3-day drainage	Mean	Continuous submergence	1-day drainage	3-day drainage	Mean
Control	3.77	3.57	3.35	3.56	3.93	3.74	3.46	3.71
75% N of RFD	4.24	4.23	3.85	4.11	4.52	4.53	4.15	4.40
100% N of RFD	4.95	4.58	4.08	4.54	5.23	5.15	4.88	5.01
150% N of RFD	5.15	4.89	4.32	4.79	5.37	5.22	4.80	5.13
75% N of RFD (25% FYM)	4.49	4.31	3.96	4.25	4.50	4.41	4.27	4.39
100% N of RFD (25% FYM)	4.90	4.70	3.92	4.51	5.18	5.03	4.67	4.96
150% N of RFD (25% FYM)	5.37	5.17	4.46	5.00	5.48	5.31	5.01	5.27
75% N of RFD + biofertilizer	4.67	4.43	4.04	4.38	4.89	4.67	4.46	4.67
Mean	4.69	4.49	4.00		4.89	4.76	4.46	
		SEm ±		*CD (P=0.05)*		*SEm±*		*CD (P=0.05)*
Irrigation (I)		0.74		0.29		0.61		0.24
Nitrogen (N)		0.19		0.54		0.17		0.47
Within N		0.26		0.76		0.23		0.67
N within I		0.27		0.56		0.22		0.49

Nitrogen uptake

Among irrigation schedules, continuous submergence resulted in maximum N uptake of 129-132 kg/ha, which was significantly superior to that under 1-day drainage and 3 day drainage. In second year, continuous submergence was similar to 1-day drainage but significantly superior to 3-day drainage (Table 3). Nitrogen fertilization recorded significantly higher total N uptake. The highest N uptake of 141.8 kg/ha in 2002 and 149.6 kg/ha in 2003 was registered with the application of 150% N of RFD (25% substituted by FYM), which was superior to other N treatments.

Application of 150% N of RFD (25% substituted by FYM) with continuous submergence registered N uptake in rice biomass (grain + straw), which was significantly higher than of 75% N of RFD (25% substituted by FYM) and the control. Similar trend was observed with 1-day drainage and 3-day drainage irrgation regimes in 2002, and 150% of RFD (25% sibstituted by FYM) was significantly higher than 75% N of RFD + biofertilizer in 2003 at all the levels of irrigation regimes.

Interactive effects of irrigation and levels of N on total N uptake were significant during both the years. Application of 150% N of RFD with continuous submergence registered the highest 153.6-157.9 kg/ha N uptake, followed by 150% N of RFD (25% substituted by FYM) with continuous submergence.

Table 3. Effect of irrigation regime and integrated nitrogen management on total N uptake (grain + straw) by rice (kg/ha)

N regime	2002				2003			
	Continuous submergence	1-day drainage	3-day drainage	Mean	Continuous submergenc	1-day drainage	3-day drainage	Mean
Control	81.6	69.2	69.4	73.4	79.0	76.5	76.3	77.3
75% N of RFD	115.7	99.3	92.4	102.5	129.2	117.4	109.3	118.6
100% N of RFD	140.5	121.5	113.0	125.0	139.7	133.6	123.4	132.2
150% N of RFD	153.6	121.6	116.2	130.5	157.9	134.7	127.8	140.1
75% N of RFD (25% FYM)	116.9	108.2	100.7	108.6	126.0	118.4	114.1	119.5
100% N of RFD (25% FYM)	148.0	124.6	112.1	128.2	142.5	137.0	126.3	135.2
150% N of RFD (25% FYM)	149.7	144.9	130.7	141.8	153.8	148.4	146.7	149.6
75% N of RDF + biofertilizer	131.0	113.6	111.1	118.6	128.1	120.6	112.5	120.4
Mean	129.6	112.9	105.7	-	132.0	124.6	117.0	
	Irrig. regime (I)		*N regime (N)*		*Irrig. regime (I)*		*N regime (N)*	
SEm±	1.3		2.6		1.6		2.8	
CD (P=0.05)	5.1		7.5		6.1		8.0	
Interaction (I × N)	*N within I*		*I within N*		*N within I*		*I within N*	
SEm±	8.6		8.5		7.5		7.5	
CD (P=0.05)	24.5		24.5		21.5		22.4	

Table 4. Influence of irrigation and integrated nitrogen management on irrigation requirement, irrigation-use efficiency, water requirement and field water-use efficiency of rice

Treatment	Irrigation requirement (mm)		Irrigation-use efficiency (kg grain/m^3 water)		Water requirement (mm)		Field water-use efficiency (kg grain/m^3 water)	
	2002	2003	2002	2003	2002	2003	2002	2003
Irrigation regime								
Continuous submergence	1,200	1,080	0.32	0.28	1,497	1,540	0.23	0.21
1-day drainage	840	680	0.34	0.44	1,137	1,150	0.32	0.32
3-day drainage	600	560	0.35	0.63	897	1,020	0.42	0.37
N regime								
Control	897	773	0.27	0.34	1,172	1,230	0.26	0.23
75% N of RFD	897	773	0.29	0.42	1,174	1,233	0.29	0.28
100% N of RFD	897	773	0.36	0.47	1,176	1,236	0.35	0.32
150% N of RFD	897	773	0.37	0.49	1,179	1,238	0.36	0.33
75% N of RFD (25% FYM)	897	773	0.32	0.45	1,178	1,239	0.31	0.30
100% N of RFD (25% FYM)	897	773	0.34	0.46	1,180	1,241	0.33	0.31
150% N of RFD (25% FYM)	897	773	0.38	0.50	1,181	1,242	0.37	0.34
75% N of RFD + biofertilizer	897	773	0.32	0.44	1,176	1,237	0.31	0.30

Agronomic N-use efficiency

Agronomic N-use efficiency was maximum with 1-day drainage (10.20 kg grains/kg N applied), followed by continuous submergence (0.90 kg grian/kg N applied), and was the least with 3-day drainage (8.85 kg grains/kg N applied). The values of Agronomic N-use efficiency (ANE) increased slightly due to application of 100% N of RFD or in combination with FYM over 150% N of RFD and 75% N of RFD levels in both the years. On an average, the crop fertilized with 100% N of RFD through fertilizer produced 11.78, and those substituted with 25% FYM produced 10.97 kg grains/kg N.

The minimum ANUE was obtained with 75% N of RFD applied through fertilizer alone. The agronomic N-use efficiency is a function of the ratio of grain yield to N applied. The 100% of RFD reflected greater utilization and contributed comparatively more grain production under 1-day drainage water regime over continuous submergence and 3-day drainage.

Moisture use

Continuous water submergence recorded more irrigation requirement (1,200 and 1,080 mm) compared with 1-day drainage (840 and 680 mm) and 3-day drainage (600 and 560 mm). The increase in irrgation requirement was 42.8 – 58.8% from 1-day drainage to continuous water submergence. The corresponding values for 3-day drainage to continuous water submergence were 100.0-92.8%. Similarly, the increase in field water requirement was 31.7 - 33.9% from 1-day drainage to continuous water submergence and 66.9 - 51.0% from 3-day drainage to continuous water submergence.

It was due to continuous water subergence, where the number of irrigations was 30 and 27 compared with 21 and 17 in 1-day drainage and 15 and 14 in 3-day drainage during first and second rainy (*kharif*) seasons respectively. Similarly, crop-water requirement was also influenced by depth of irrigation water in the respective regimes. The field water requirement was less in second year than in first year due to higher rainfall during the second year (Table 4).

Maximum irrigation-water use efficiency (kg grains/m^3 water used) of 0.35 and 0.63 and field-crop water-use efficiency of 0.42 and 0.37 were obtained with 3-day drainage, followed by 1-day drainage and the least with continuous water submergence (Table 5). It is obvious that irrigation water-use efficiency and field water-use efficiency are the functions of the ratio of economic grain yield to water applied and water requirement of the crop. Maximum irrigation-use efficiency and field water-use efficiency (kg grains/m^3 water) were observed with 150% N of RFD (25% substituted by FYM) than other N treatments. This is because the applied N led to higher grain yield than crop water use, resulting in higher IUE and FWUE.

REFERENCES

Dar, S.A., Bali, A.S. and Shah, M.H. 2000. Effect of different levels and time of nitrogen application on wet-seeded rice in Kashmir Valley. *Oryza* **37**(3): 244–246.

Government of India, New Delhi. 2005. *Economic Survey, 2004-2005*. Agriculture. Economic Division, Ministry of Finance, Government of India, New Delhi, pp. 154–173.

Ikeda, M. and Watanabe, T. 2002. Effectiveness of ammonium nitrogen and nitrate-nitrogen in irrigation water in paddy rice without top dressed nitrogen at the panicle formation stage. *Science Bulletin of the Faculty of Agricuture, Kyushu University* **56**(2): 131–137.

Jayaprakash, T. and Wahab, K. 1995. Influence of water regimes and fertilizer on the growth and yield of direct seeded rice. *Madras Agricultural Journal* **82**(6-8): 462–463.

Manguiat, I.J., Mascarina, G.B., Ladha, J.K., Buresh, R.J. and Tallada, J. 1994. Prediction of nitrogen availability and rice yield in lowland soils : nitrogen mineralization parameters. *Plant and Soil* **160**: 131–137.

Novoa, R. and Loomis, R.S. 1981. Nitrogen and plant production. *Plant and Soil* **58**(1): 177–204.

Pathak, H., Bhatia, Arti, Prasad, Shiv, Singh, Shalini, Kumar, S., Jain, M.C., Singh, P., Bhatia, A., Prasad, S. and Singh S. 2003. Effect of DCD, FYM and moisture regime on nitrous oxide emission from an alluvial soil in rice-wheat cropping system. *Journal of the Indian Society of Soil Science* **51**(2): 139–145.

Prasad, R. 1998. Fertilizer urea, food security, health and the environment. *Current Science* **75**: 677–683.

Sharma, S.K. and Sharma, S.N. 2002. Integrated nutrient management for sustainability of rice and wheat cropping system. *Indian Journal Agricultural Sciences* **72**(10): 573–576.

Timsina, Jagdish, Singh, Upendra, Mohammed, Badaruddin and Meisner, C. 1998. Cultivar, nitrogen and moisture effects on a rice-wheat sequence : experimentation and simulation. *Agronomy Journal* **90**: 119–130.