

Original Research Article

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## Drip Irrigation and Fertigation Effects on Aerobic Rice (*Oryza sativa*) in Semi-Arid Conditions of Telangana State, India

B. Padmaja\* and M. Malla Reddy

Department of Agronomy, College of Agriculture, Prof. Jayashankar Telangana State  
Agricultural University, Rajendranagar, Hyderabad-030, Telangana State, India

\*Corresponding author:

### ABSTRACT

A field experiment was conducted during rainy season of two consecutive years (2011 and 2012), in sandy loam soils of Warangal, Telangana State to study the response of aerobic rice (*Oryza sativa* L.) to drip irrigation and nitrogen fertigation under semi-arid environment. The experiment was laid out in split plot design with four replications. Three irrigation schedules viz. drip irrigation at 100% Pan Evaporation (PE); 150% PE and 200% PE were taken as main plots and three nitrogen levels through fertigation viz. 90, 120 and 150 kg/ha were taken as subplots. The data revealed that the growth parameters of aerobic rice like LAI, SPAD chlorophyll meter reading, tillers/m<sup>2</sup> and drymatter accumulation were significantly higher in 200% PE schedule compared to that of 100% PE but comparable with 150% PE except for drymatter accumulation. Drymatter accumulation at maturity, root volume and dry weight were more at 200% PE compared to that of lower schedules. The number of panicles/m<sup>2</sup> and filled spikelets/ panicle increased from 100% PE to 150% PE but not at 200% PE while sterility of spikelets was higher with 100% PE schedule. Higher grain and straw yield, nitrogen uptake and economics were recorded with 200% PE over the other two schedules. Irrespective of the irrigation schedules, growth parameters (plant height, LAI, SPAD meter reading, tillers/m<sup>2</sup> and drymatter accumulation), yield attributes (panicles/m<sup>2</sup>, panicle length and filled spikelets/panicle) increased with level of N application from 90 to 120 kg N/ha while root volume and dry weight were higher at 150 kg N/ha. The number of days taken to reach 50 per cent flowering was not influenced by irrigation schedules but influenced by the nitrogen levels during first year in which the plots supplied with 150 kg N/ha flowered earlier than other N levels. The sterility of spikelets was higher at 90 kg N/ha compared to other doses. Grain yield, straw yield, nitrogen uptake and economic parameters were higher at 150 kg N/ ha compared to lower N levels. Water use-efficiency reduced with increased water input from 100% PE schedule to 200% PE but increased with the increase in N level from 90 to 150 kg N/ha during both the years of study. In contrary, nitrogen use efficiency was enhanced with the increase in water input in drip irrigation and reduced with the increase in N level of application. Gross returns, net returns and benefit: cost ratio were higher in drip irrigation schedule of 200% PE and 150 kg N/ha closely followed by that realized at 120 kg N/ ha in the same irrigation schedule.

### Keywords

Aerobic rice, Drip irrigation, Fertigation, Nitrogen-use efficiency, Root volume, Water-use efficiency and Yield

### Article Info

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## Introduction

Traditional rice production involves submerged conditions with approximately 5 to 10 cm deep standing water throughout the crop growth period. This system requires around 3000 to 5000 litres of water for producing one kg of grain which is about twice or even more than that for wheat or maize (Joshi *et al.*, 2009). It is the single largest user of fresh water consuming about 30 per cent and more than 45 per cent of total fresh water used in World and Asia, respectively (Barker *et al.*, 1999). The increasing scarcity of fresh water for agriculture and the competing demand from the non-agricultural sector threaten the sustainability of the irrigated rice ecosystem. To cope up with scarcity, several water saving technologies have been developed for rice.

The International Rice Research Institute (IRRI) developed aerobic rice technology, wherein the crop is established in non-puddled, non-flooded fields and rice is grown like an upland crop with adequate inputs and supplementary irrigation when rainfall is insufficient (Bouman and Tuong, 2001 and Prasad, 2011). Farmers in Brazil, China and India are pioneering this system where water is scarce or costly. Aerobic rice cultivation saves water input and increases water productivity by reducing water use during land preparation and limiting seepage, percolation and evaporation (Peng *et al.*, 2012). It also reduces labour requirement and greenhouse gaseous emission from rice field. However, many recent studies have revealed a yield penalty of rice under aerobic cultivation (George *et al.*, 2002; Belder *et al.*, 2005; Peng *et al.*, 2006 and Mallareddy and Padmaja, 2013). The shift from puddled to aerobic soil conditions brings profound changes in soil water status, aeration, soil organic matter turnover, nutrient dynamics, carbon impounding, weed flora and greenhouse gas

emissions (Farooq *et al.*, 2009 and Prasad, 2011).

To make aerobic rice successful, new varieties and new management practices need to be developed. Optimum irrigation scheduling and nitrogen nutrition is critical for profitable yield realization of irrigated rice ecosystems (Maheswari *et al.*, 2008). Drip irrigation and fertigation methods have been proved to be the water and nutrient efficient methods, respectively in most of the crops apart from increasing the productivity. Aerobic rice with micro irrigation practices leads to sustainable rice production for immediate future to address water scarcity with more benefits and environmental safety in the scenario of global warming by reduced methane emission is an added advantage (Parthasarathi *et al.*, 2012). Realising the need of increasing the water productivity, many State Governments are providing huge subsidies to farmers for drip irrigation.

In aerobic system, the dominant form of nitrogen is nitrate and relatively little ammonia volatilization is expected after fertilizer nitrogen application. The alternate moist and dry soil conditions may stimulate nitrification-denitrification processes in dry sown rice, resulting in loss of nitrogen through  $N_2$  and  $N_2O$ . The differences in soil N dynamics and pathways of nitrogen losses in dry sown rice system may result in different fertilizer nitrogen recoveries. With even high nitrogen applications in aerobic rice, grain filling may be limited by a low contribution of post-anthesis assimilates (Zhang *et al.*, 2009). In addition, in the absence of transplanting, the roots of aerobic rice are located in the shallow surface soil, which results in a relatively low uptake of nitrogen (Zhang and Wang, 2002). Keeping this in view, an attempt was made to evaluate the performance of aerobic rice under drip irrigation and nitrogen fertigation.

## Materials and Methods

A field experiment was conducted during the rainy season of 2011 and 2012 at Regional Agricultural Research Station, Warangal (18°00'53.2" N, 79°36'17.2" E and 275 m above mean sea level), Telangana State, India. Climate of the study site is sub-tropical and semi-arid type with mean annual rainfall of 885 mm and a mean annual evaporation of 1621 mm. Soil of the experimental field was sandy loam with pH of 7.9, Electrical conductivity (EC) 0.17 d S/m, low in organic C (0.40%), available N (227 kg/ha), available P (11 kg/ha) and available K (65 kg/ha). The weekly mean maximum temperature ranged from 27.1°C to 33.0°C and 26.1°C to 30.6°C during 2011 and 2012, respectively. The mean minimum temperature for the corresponding period ranged from 22.3 °C to 26.1 °C and 20.0 °C to 26.0°C, respectively, while the average maximum and minimum temperatures during the same period were 30.5 °C and 24.0 °C during 2011, and 28.7 °C and 23.3 °C during 2012, respectively. The weekly mean relative humidity ranged from 60.1 to 81.1 per cent during 2011 and 74.6 to 80.3 per cent during 2012, while the average relative humidity was 72.7 per cent and 76.9 per cent, during 2011 and 2012, respectively. A total rainfall of 349.2 mm and 784.0 mm was received on 26 and 53 rainy days during 2011 and 2012, respectively. The total evaporation during the growing season of rice was 379 and 387.9 mm during 2011 and 2012, respectively. The weekly mean bright sunshine hours per day varied from 1.5 to 7.0 hours and 0.7 to 9.2 hours during 2011 and 2012, respectively. Treatments consisting of three irrigation regimes viz. drip irrigation at 100% Pan Evaporation (PE), 150% PE and 200% PE in main plots and three nitrogen levels through fertigation (90, 120 and 150 kg/ha) in subplots were tested in a split-plot design and replicated four times. The cultivar used for the study was 'WGL 20471' (Erramallelu) with

medium duration (120 days), fine grain, drought tolerant and good cooking quality.

The field was dry-ploughed and harrowed but not puddled during land preparation. Seed were sown in solid rows at a spacing of 30 cm between the rows in favourable soil moisture condition for germination. Thinning and gap filling was done at 10 days after sowing. Weeds were controlled by pre-emergence application of pendimethalin@ 1.2 kg a.i/ha followed by pyrazosulfuron ethyl@ 30 g. a.i/ha at 20 days after sowing. Nitrogen was applied as per the treatments in the form of water soluble specialty fertilizers (urea phosphate and urea) as fertigation through ventury fitted to the drip system. The entire dose was split into ten equal parts and applied through drip at weekly interval starting from ten days after sowing. P<sub>2</sub>O<sub>5</sub> was supplied @ 60 kg/ha as urea phosphate during first fertigation uniformly to all the treatments. Potassium@ 50 kg K<sub>2</sub>O/ha as muriate of potash was applied to all the treatments at the time of sowing as basal dose. To correct the 'Fe' deficiency which occurred at 20-30 DAS, ferrous sulphate was applied @5g/lt for three times at weekly interval. To control yellow mite, dicofol @3g/lt was sprayed at 50 DAS and to control blast, tricyclozole @0.6 g/lt was sprayed at 90 DAS.

Drip irrigation was given every alternate day as per the schedules based on the evaporation from open pan evaporimeter (USWB class A) situated at Regional Agricultural Research Station, Warangal. The laterals of 16 mm diameter were laid out at 60 cm apart with a spacing of 50 cm distance between two inline emitters. The emitter discharge was 4.0 lt/hr and application rate was 13.33 mm/hr. Control valves were fixed in all the plots to facilitate controlling the water flow as per the treatments. During rainy days, the quantity of water applied to each treatment was adjusted for the rainfall received.

Data on growth, yield attributes, yield and N uptake were recorded at different intervals and crop maturity. Root volume (cc/hill) was measured by water displacement method as described by Misra and Ahmed (1987). The roots after recording the volume were kept in hot air oven at 60<sup>0</sup>C till the constant weight was obtained and expressed as g/plant. Standard procedures were used for chemical analysis of soil and plant samples. The economic parameters (gross returns, net returns and benefit: cost ratio) were worked out on the basis of prevailing market prices of inputs and outputs. Water use efficiency (WUE) was calculated as grain yield per total water received from rainfall and irrigation and expressed as:  $WUE = Y/R+I$  (kg/ha-mm). Nitrogen-use efficiency (NUE) (kg grain/kg applied N) was calculated using the equation:  $NUE = Y/N$ ; where Y is the grain yield (kg/ha); R is the amount of effective rainfall (mm); I is the amount of irrigation water applied (mm) and N is the quantity of N applied (kg). The data were analyzed by using the 'Analysis of Variance Technique' as per the procedures described by Panse and Sukhatme (1985). The treatments means were compared at 5% level of significance.

## Results and Discussion

### Growth parameters

Drip irrigation and N fertigation significantly influenced the growth parameters of aerobic rice. Plant height at 30 DAS, leaf area index (LAI), SPAD chlorophyll meter reading and number of tillers/m<sup>2</sup> at all the stages of observation were significantly increased in 200% PE compared to that of 100% PE but comparable with 150% PE during first year of experimentation (Fig. 1 to 5). During second year (2012), plant height, tiller number, SPAD chlorophyll meter reading at all the stages of observation and drymatter accumulation upto 90 DAS remained largely unaffected by the

irrigation schedules. It is attributed to evenly distributed and 128% more rainfall than that received during first year which occurred upto panicle initiation stage. Hence, the effect of irrigation schedules could not be observed. However, drymatter accumulation at all the stages during first year and at maturity during second year was significantly higher with 200% PE schedule compared to the other two schedules. All the growth parameters viz. plant height, LAI, SPAD chlorophyll meter reading, number of tillers/ m<sup>2</sup> and drymatter accumulation increased with the increase in N level from 90 to 120 kg N/ ha (Fig. 6 to 10). Application of higher nitrogen dose result in taller plants and larger leaf area which increase in the photosynthate production in turn enhances the drymatter production in rice. The results are in consonance with that of Belder *et al.*, (2005), Maheswari *et al.*, (2008), Sathiya *et al.*, (2008) and Kadiyala *et al.*, (2012).

The number of days taken to reach 50 per cent flowering in aerobic rice did not differ due to irrigation schedules but differed by the nitrogen levels during 2011 in which the plots supplied with 150 kg N/ha flowered earlier than the plots which received 120 kg but was on a par with 90 kg N/ha (Table 1).

### Root volume and dry weight

Root volume (cc/hill) and dry weight (g/hill) of rice measured at 50% flowering was influenced by the irrigation schedules and nitrogen levels in fertigation (Table 1). Higher root volume was observed with drip irrigation at 200% PE which was significantly superior to that with 100% PE during both the years of study but differed with 150% PE only during 2012. This could be attributed to the congenial soil-moisture environment promoting root growth on account of additional water availability in higher irrigation schedule (Ghosh *et al.*, 2012). The irrigation schedules

of 100 and 150% PE were on a par with each other. Greater vigour of root has additional advantages encouraging root penetration to the deeper zone, which could accelerate extraction of subsurface soil water effectively (Bouman and Tuong, 2001 and Kato *et al.*, 2007). Additionally, increased nutrient uptake and greater N use efficiency were also associated with better root development (Peng and Bouman, 2007 and Richards, 2008). Root volume measured in the plots where 150 kg N/ha was applied through fertigation was significantly superior to that in 90 kg N/ha during both the years and 120 kg N/ha during 2011. Even, a small difference in root growth may result in large difference in water and nutrients uptake (Henry *et al.*, 2011). The above results confirm the findings of Maheswari *et al.*, (2008) and Mahajan *et al.*, (2012).

### **Yield attributes**

Yield attributes of aerobic rice were also influenced by irrigation schedules and nitrogen levels in drip fertigation. Number of panicles/ m<sup>2</sup> were significantly higher at 200% PE compared to that of 100% PE but on par with that of 150% PE. Number of filled spikelets/ panicle increased upto 150% PE during 2011 and upto 200% PE during 2012 (Table 2). The percentage of sterile spikelets was higher in 100% PE schedule. Panicle length and test weight did not differ due to irrigation schedules. Higher number of panicles at 200% PE drip irrigation schedule might be due to favourable moisture conditions during panicle initiation stage which was beneficial in maintaining normal cell integrity, cell division and elongation apart from enhancing nutrient uptake (Singh, 2004) and finally led to increased sink size. A little water deficit at the anthesis stage of rice induce a high percentage of spikelet sterility and reduce grain yields (De Datta, 1989). Water stress at flowering affects physiological

processes such as anther dehiscence (Ekanayake *et al.*, 1990), pollen germination (Saini and Westgate, 2000), panicle exertion (O'Toole and Namuco, 1983), peduncle length (He *et al.*, 2009) and finally are responsible for increased sterility. Drought stress during late panicle development also sharply decreases the percentage of filled grains (Fageria, 2001).

Similar to growth parameters, panicles/ m<sup>2</sup>, panicle length and spikelets/ panicle increased from 90 to 120 kg/ N ha applied in fertigation but comparable between 120 and 150 kg N/ ha while sterility of spikelets was more with 90 kg N/ ha. Test weight was found significantly reduced under 150 kg N/ha compared to the lower doses during 2011 but remained same with all the N levels during the second year of study. Increased nitrogen application under fertigation might have led to availability of N in sufficient quantities required by the crop which encouraged the increased sink formation. These results are in line with the reports of Venugopal (2005), Halder *et al.*, (2008) and Ramesh *et al.*, (2009).

### **Yield and nitrogen uptake**

Significant increase in grain yield was observed from 100% PE to 150% PE (24%) and then to 200% PE (24%) during both the years (Table 3). Similar trend was noticed in straw yield also. Higher harvest index was obtained with irrigating at 200% PE compared to 100% PE during first year but not during second year. Grain yield is mostly limited by sink capacity and the ability of grain to accept assimilates (Fukai *et al.*, 1991). Grain yield decreased with the reduced input of water in the present study. This might be because of the negative effect of water stress on photosynthetic process and its partitioning ability towards sink and on the yield components like number of grains and 1000-grain weight which was demonstrated in this

experiment. N uptake by grain and straw also varied among the irrigation schedules. It was significantly increased with water input increasing from 100% PE to 200% PE during both the years of study.

Increasing the nitrogen supply from 90 to 150 kg/ha increased the rice yield significantly under fertigation (Table 3). The highest grain yield was recorded at 150 kg/ha during both the years. It increased by 13 and 16 per cent during 2011 and 2012, respectively with the application of 120 kg N/ ha over 90 kg/ ha. It again increased by 7 and 9 per cent, respectively with 150 kg/ ha compared to 120 kg/ ha. A study conducted by Zhang *et al.*, (2009) in China suggested that in aerobic rice, more carbohydrates from post-anthesis photosynthesis are needed for grain filling.

The regime of fertilizer-N application needs to promote the contribution of drymatter production between pre-anthesis and post-anthesis to achieve a high percentage of filled grains and thus a high harvest index. In another study conducted by Kadiyala *et al.*, (2012) at Hyderabad, 48-58 per cent of applied nitrogen depending on the dose was found to be lost from soil-plant system in aerobic rice. Converting flooded rice to water saving systems such as aerobic system result in high N losses accompanied by upto 50 per cent reduction in N use efficiency. Hence, matching N application to crop demand is the key to reduce NO<sub>3</sub>-N leaching and maintain crop yield (Fang *et al.*, 2006). Fertigation can potentially spoon feed the nutrients to a crop which accurately supplies the crop's nitrogen needs throughout the season, enhance crop yield and reduce the potential for groundwater contamination from nitrates (Lamm *et al.*, 2001). Straw yield and harvest index also followed the similar trend but not differed during first year and second year, respectively. The N uptake by grain was higher with 150 kg N/ ha but increased upto 120 kg N/ ha only by

the straw. The interaction effect between the irrigation schedules and nitrogen levels was not significant in any of the parameters studied.

#### **Water-use efficiency and nitrogen-use efficiency**

Water-use efficiency gradually reduced with increased water input from 100% PE schedule to 200% PE but increased with the increase in N level from 90 to 150 kg N/ ha during both the years of study (Table 4).

Similar findings had been brought out by many workers (Shekara *et al.*, 2010 and Sridharan and Vijayalakshmi, 2012). Increase in N levels from 90 to 150 kg N/ ha through fertigation resulted in higher water productivity which might be attributed to increased yield under higher nitrogen levels with a constant rate of applied water. It was increased by 14.8, 18.0 and 22.2, 27.9 per cent at 120 and 150 kg compared to 90 kg N/ha during 2011 and 2012, respectively. This was in agreement with Belder *et al.*, (2005), Maheswari *et al.*, (2008) and Mallareddy *et al.*, (2013).

Nitrogen use efficiency (NUE) (kg grain/kg N applied) of aerobic rice enhanced with the increase in water input from 100% PE to 200% PE through drip irrigation during both the years of study (Table 4). With the increase in the level of nitrogen, NUE gradually decreased in aerobic rice. The highest NUE was recorded with 90 kg /ha.

The mean NUE of two years with 150 and 120 kg N/ ha decreased by 26 and 14 per cent, respectively compared to the lower dose. This was in accordance to the statement that crop response to applied nutrients typically follows a diminishing return function as yields approach the potential limit (Hegde *et al.*, 2007).

### Economics

Gross returns, net returns and benefit: cost ratio were higher in drip irrigation schedule of 200% PE and 150 kg N/ ha closely followed by that realized at 120 kg N/ ha in the same irrigation schedule (Table 5). The above economic parameters were lower with 100% PE irrigation schedule and 90 kg N/ ha.

Higher moisture regime was reported to realize greater net returns and benefit: cost ratio in several studies (Shekara *et al.*, 2010 and Murthy and Reddy, 2013). In general, the net returns and benefit: cost ratio was lower during 2012 despite of increased yield. It was due to the lower minimum support price for the rice grain prevailed in 2012 compared to the same during 2011.

### Post-harvest status of available N P K

Considerable variation in soil available N status was observed after harvest of rice crop due to different irrigation schedules and nitrogen levels (Table 6).

Soil available N was higher at increased N level from 90 to 150 kg/ ha at all the irrigation schedules, while it decreased from the irrigation schedules of 100% PE to 150% PE at all the N levels, during both the years of study. The data also indicated that available P and K status of the soil after harvest of rice crop did not differ much due to irrigation schedules or nitrogen levels under drip fertigation.

**Table.1** Root volume, root dry weight, days to 50% flowering in aerobic rice as influenced by irrigation regimes and N levels through fertigation

Treatment	Root volume (cc/hill)		Root dry weight (g/hill)		Days to 50% flowering	
	2011	2012	2011	2012	2011	2012
<b>Irrigation regime</b>						
100% PE	22.5	18.7	7.9	6.7	95.3	95.7
150% PE	25.6	19.2	9.1	7.6	93.7	95.1
200% PE	27.7	23.5	11.4	9.0	93.9	94.6
SEm±	1.00	0.62	0.28	0.16	0.81	0.53
CD (P=0.05)	3.50	2.10	1.00	0.60	NS	NS
<b>N level (kg/ha)</b>						
90	21.3	18.2	8.1	7.0	94.6	94.9
120	24.4	20.9	9.6	7.7	95.2	95.2
150	30.0	22.3	10.7	8.7	93.2	95.3
SEm±	0.70	0.62	0.26	0.15	0.46	0.32
CD (P=0.05)	2.10	1.90	0.80	0.40	1.40	NS
<b>Interaction</b>						
SEm±	1.74	1.08	0.49	0.28	1.41	0.92
CD (P=0.05)	NS	NS	NS	NS	NS	NS

**Table.2** Yield attributes of aerobic rice as influenced by irrigation regimes and N levels through fertigation

Treatment	Panicles/m <sup>2</sup>		Panicle length (cm)		Filled spikelets/panicle		Sterility (%)		Test weight (g)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
<i>Irrigation regime</i>										
<b>100% PE</b>	221	233	21.3	22.3	146	122	15.5	12.4	16.8	16.9
<b>150% PE</b>	249	263	23.1	22.0	197	167	10.6	11.3	17.1	17.6
<b>200% PE</b>	290	306	23.8	23.6	215	209	11.0	9.1	17.1	17.2
<b>SEm±</b>	11.8	12.4	0.70	0.51	9.3	10.8	0.99	0.49	0.11	0.20
<b>CD (P=0.05)</b>	41.0	43.0	NS	NS	32.0	37.0	3.40	1.70	NS	NS
<i>N level (kg/ha)</i>										
<b>90</b>	224	236	20.9	20.8	166	147	14.0	12.4	12.4	17.1
<b>120</b>	253	267	23.0	23.0	185	168	11.9	10.6	10.6	17.4
<b>150</b>	283	298	24.3	24.1	207	182	11.2	9.8	9.8	17.2
<b>SEm±</b>	10.5	11.1	0.26	0.75	7.0	6.9	0.72	0.39	0.39	0.20
<b>CD (P=0.05)</b>	31.0	33.0	0.80	2.20	21.0	21.0	2.10	1.20	1.20	NS
<i>Interaction</i>										
<b>SEm±</b>	20.4	21.5	1.20	0.88	16.1	18.6	1.72	0.85	0.19	0.35
<b>CD (P=0.05)</b>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**Table.3** Yield, harvest index and N uptake of aerobic rice as influenced by irrigation regimes and N levels through fertigation

Treatment	Grain yield (kg/ha)		Straw yield (kg/ha)		Harvest Index		N uptake by grain (kg/ha)		N uptake by straw (kg/ha)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
<i>Irrigation regime</i>										
<b>100% PE</b>	2474	3048	3664	5557	40.2	40.1	28.4	33.4	20.8	33.2
<b>150% PE</b>	3263	3540	4837	6852	40.4	41.3	41.7	45.3	27.3	42.7
<b>200% PE</b>	4073	4349	5783	8979	42.6	42.3	59.5	60.6	35.4	61.2
<b>SEm±</b>	158.1	142.4	218.9	374.8	0.58	0.56	2.52	2.53	0.92	4.03
<b>CD (P=0.05)</b>	546	492	756	1294	2.0	NS	8.7	8.7	3.2	13.9
<i>N level (kg/ha)</i>										
<b>90</b>	2998	3199	4508	5954	39.8	39.6	37.4	37.4	24.2	38.8
<b>120</b>	3385	3711	4793	7301	41.3	41.5	43.3	47.0	28.2	41.5
<b>150</b>	3628	4027	4984	8133	42.1	42.6	48.9	55.0	31.1	56.8
<b>SEm±</b>	72.1	85.5	156.0	225.1	0.63	0.58	1.71	1.86	1.19	3.16
<b>CD(P=0.05)</b>	214	254	NS	669	1.90	1.70	5.10	5.50	3.60	9.40
<i>Interaction</i>										
<b>SEm±</b>	273.8	246.7	379.2	649.2	1.01	0.96	4.37	4.39	1.9	6.98
<b>CD (P=0.05)</b>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**Table.4** Water- and nitrogen use efficiency of aerobic rice as influenced by irrigation regimes and N levels through fertigation

Treatment	WUE (kg/ha-mm)		NUE (kg grain/kg N applied)	
	2011	2012	2011	2012
<i>Irrigation regime</i>				
<b>100% PE</b>	6.1	7.7	20.95	25.69
<b>150% PE</b>	5.9	6.8	28.10	30.19
<b>200% PE</b>	5.8	6.7	36.66	37.44
<i>N level (kg/ha)</i>				
<b>90</b>	5.4	6.1	33.31	35.55
<b>120</b>	6.2	7.2	28.21	30.92
<b>150</b>	6.6	7.8	24.18	26.85

**Table.5** Economics of aerobic rice as influenced by the irrigation schedules and N levels through fertigation

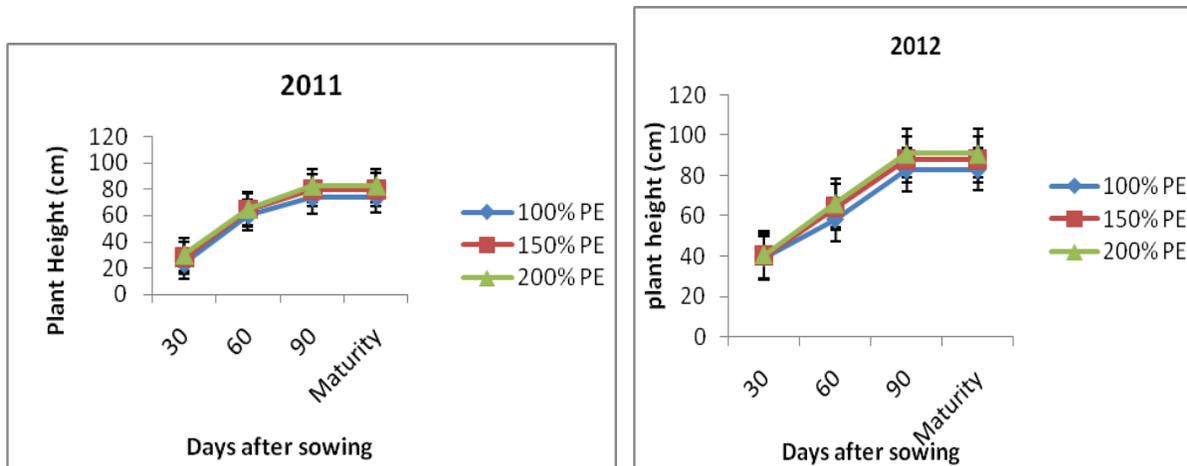
Treatment		2011			2012		
Irrigation regime	Nitrogen level (kg/ha)	Gross returns (₹ /ha)	Net returns (₹ /ha)	Benefit: cost ratio	Gross returns (₹ /ha)	Net returns (₹ /ha)	Benefit: cost ratio
<b>100 % PE</b>	90	30410	5787	0.24	31093	6470	0.26
	120	41944	16944	0.68	40378	15378	0.62
	150	42637	17260	0.68	47052	21675	0.85
<b>150 % PE</b>	90	48156	23433	0.95	39181	14458	0.58
	120	46161	24061	0.96	48718	23618	0.94
	150	52179	26702	1.05	50083	24606	0.97
<b>200 % PE</b>	90	56578	31755	1.28	49623	24800	1.00
	120	62374	37174	1.48	54687	29487	1.17
	150	66989	41412	1.62	59297	33720	1.32

Price (2011): Grain- ₹ 13.1/kg ; Straw: ₹ 1.0/ kg  
 Price (2012): Grain- ₹ 10.8 /kg; Straw: ₹ 1.0/ kg

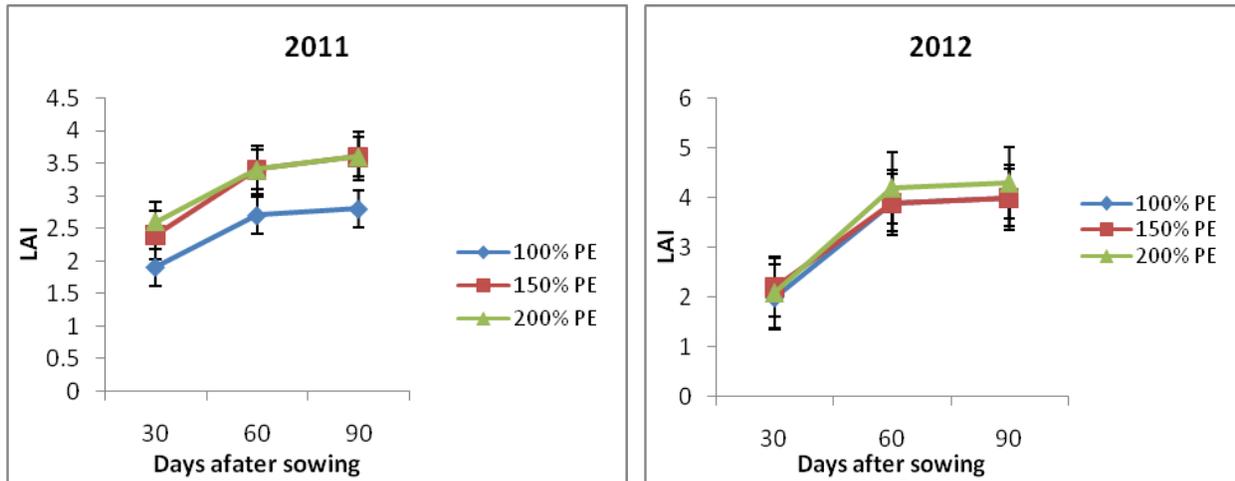
**Table.6** Soil N P K status (kg/ha) after harvest of rice crop as influenced by the irrigation schedules and N levels through fertigation

Treatment		2011			2012		
Irrigation schedule	Nitrogen level (kg/ha)	N	P	K	N	P	K
<b>100 % PE</b>	90	258.6	11.5	74.1	245.9	13.2	64.9
	120	263.6	10.8	68.8	250.4	10.2	65.5
	150	303.2	10.2	66.4	321.5	10.8	68.4
<b>150 % PE</b>	90	243.3	10.8	71.1	215.4	10.4	58.8
	120	261.7	9.7	64.5	231.7	9.8	56.6
	150	288.7	9.6	58.3	283.6	9.4	58.1
<b>200 % PE</b>	90	218.6	10.1	62.8	133.4	8.8	59.2
	120	234.7	9.8	58.7	185.8	8.5	58.1
	150	256.4	8.4	54.4	188.6	8.3	56.6

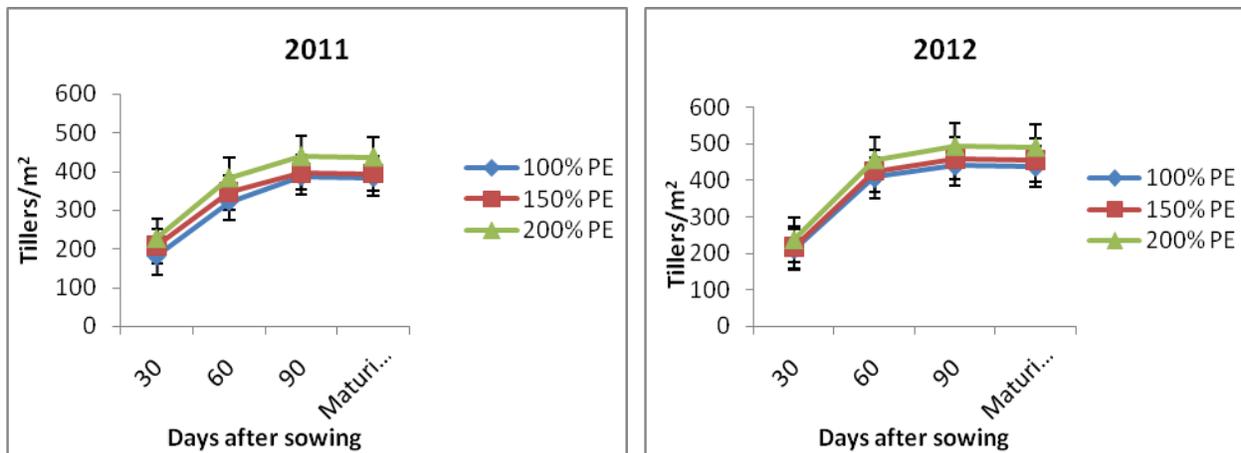
**Fig.1** Plant height (cm) of aerobic rice at different growth stages as influenced by irrigation regimes under drip irrigation



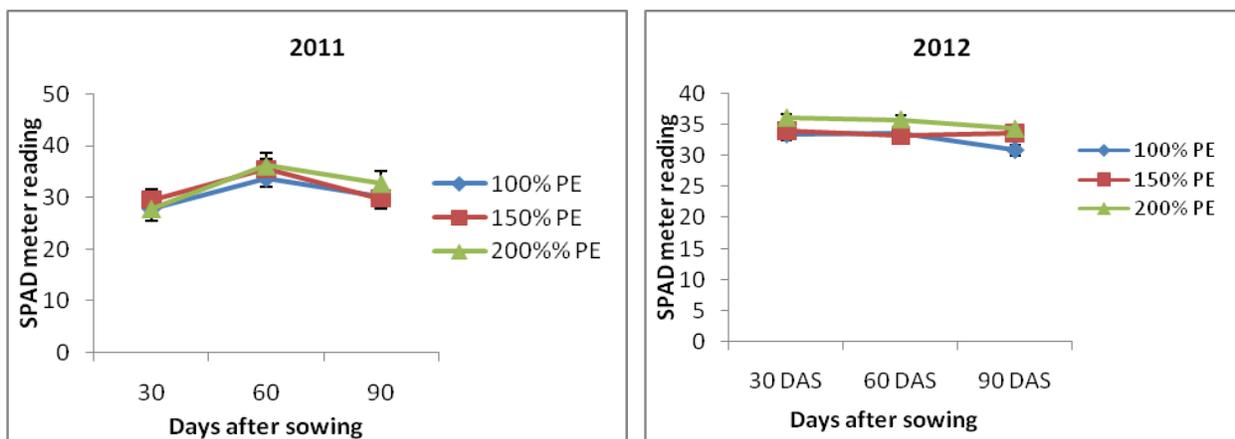
**Fig.2** Leaf Area Index of aerobic rice at different growth stages as influenced by irrigation regimes under drip irrigation



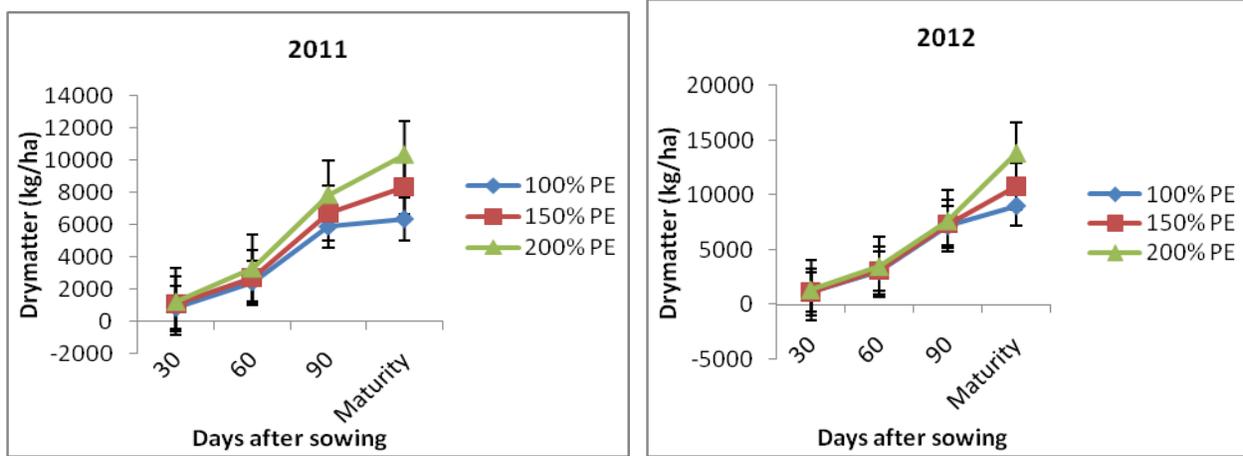
**Fig.3** Tiller production of aerobic rice at different growth stages as influenced by irrigation regimes under drip irrigation



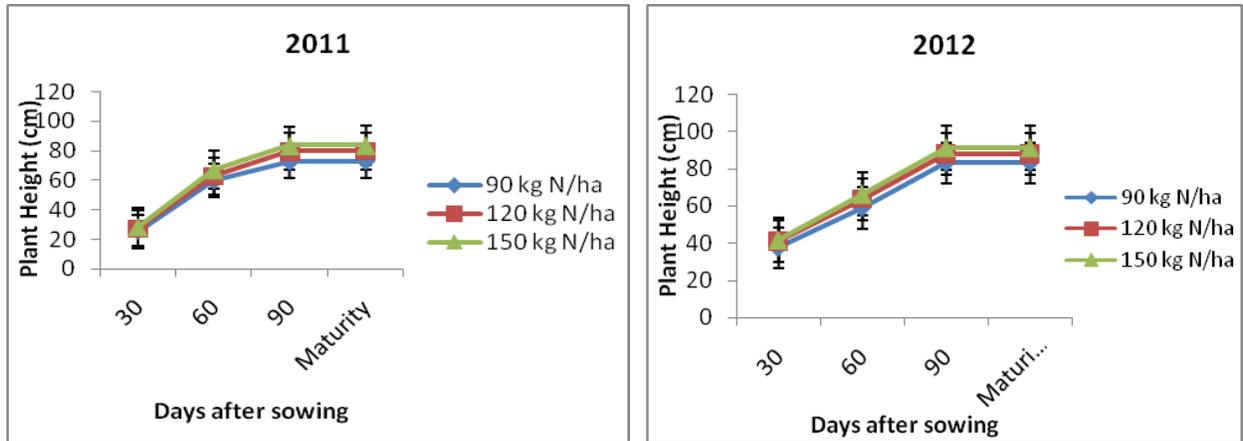
**Fig.4** SPAD meter reading of aerobic rice at different growth stages as influenced by irrigation regimes under drip irrigation



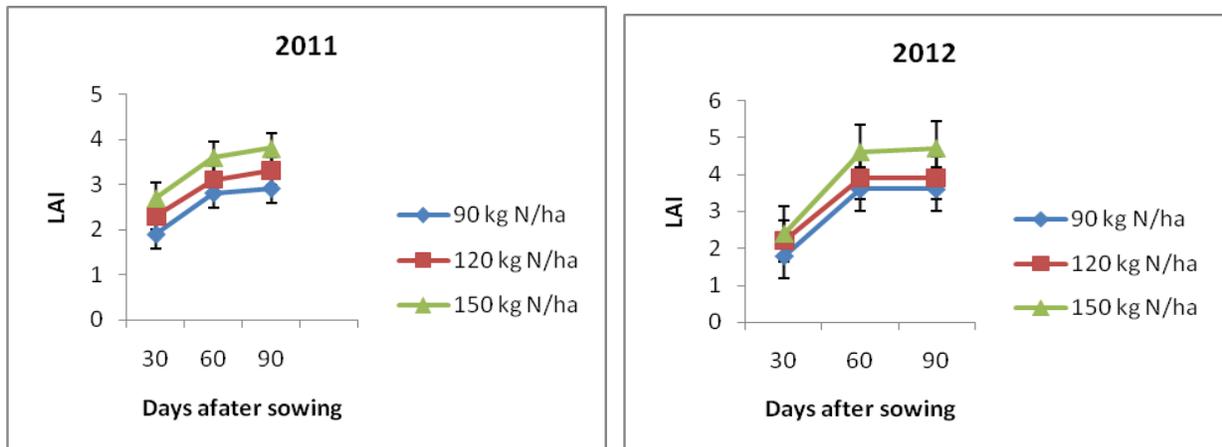
**Fig.5** Drymatter production (kg/ha) of aerobic rice at different growth stages as influenced by irrigation regimes under drip irrigation



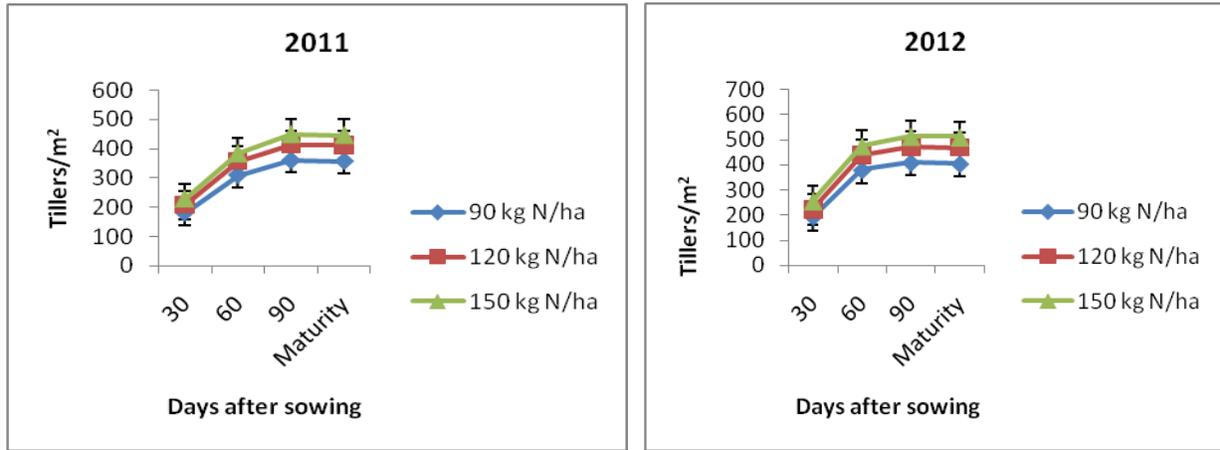
**Fig.6** Plant height (cm) of aerobic rice at different growth stages as influenced by nitrogen fertigation



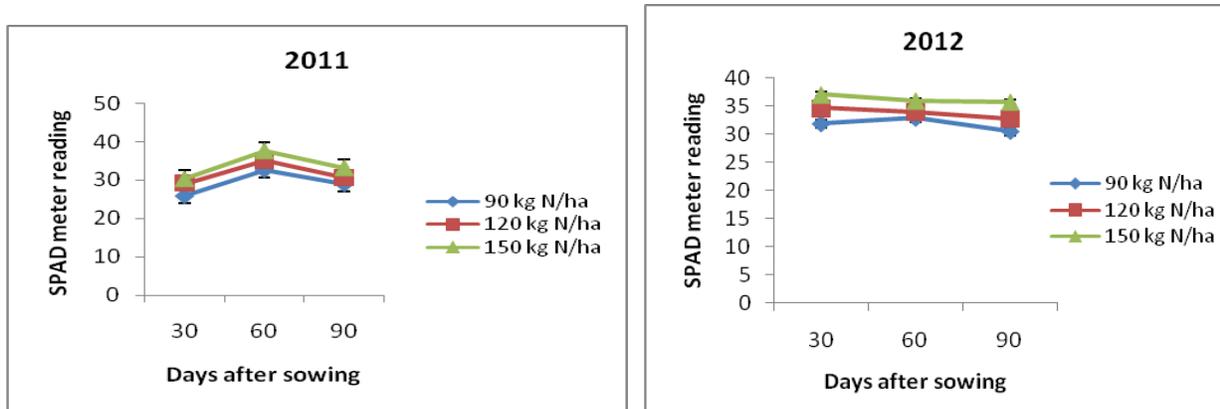
**Fig.7** Leaf Area Index of aerobic rice at different growth stages as influenced by nitrogen fertigation



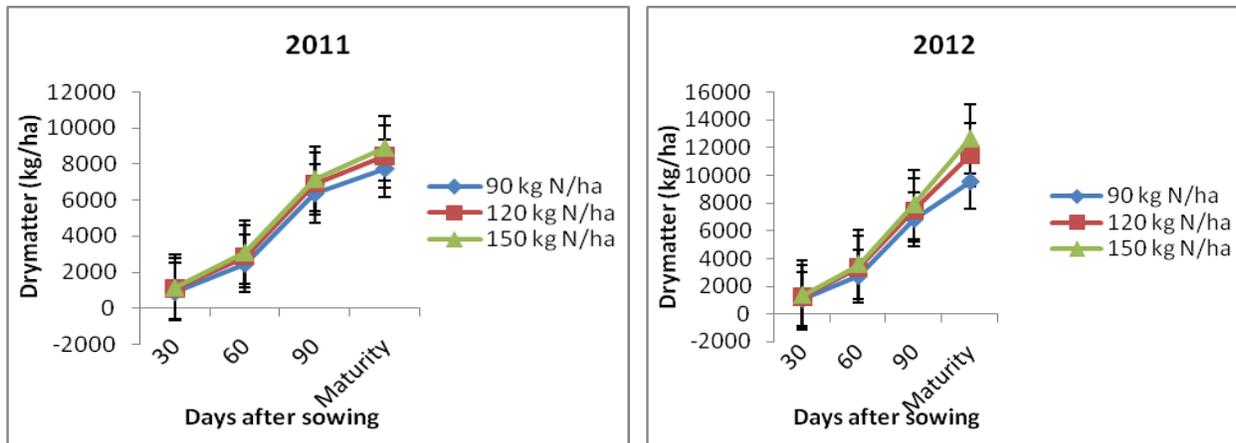
**Fig.8** Tiller production of aerobic rice at different growth stages as influenced by nitrogen fertiligation



**Fig.9** SPAD meter reading of aerobic rice at different growth stages as influenced by nitrogen fertiligation



**Fig.10** Drymatter production (Kg/ha) of aerobic rice at different growth stages as influenced by nitrogen fertiligation



From the present study, we conclude that growing aerobic rice under drip irrigation by replenishing the water twice that evaporated from open pan (200% PE) along with fertigation at 150 kg N/ha appears to increase the yields of rice under aerobic system thus helping to bridge the gap between flooded and aerobic cultivation.

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