# EVALUATION OF DRIP IRRIGATION AND FERTIGATION LEVELS IN AEROBIC RICE FOR HIGHER WATER PRODUCTIVITY

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## ABSTRACT

A field study was conducted to evaluate the potential of surface drip under variable climate based schedules and N-fertigation levels on growth and yield of aerobic rice in semi-arid region of India.The experiment was conducted for three years (*kharif* 2012, 2013 and 2014) in split plot design with 3 replications at Water Technology Centre, College of Agriculture, Prof. Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, India.The main treatments consisting of 3 drip irrigation schedules (at 100,150 and 200 % pan evaporation replenishment) and the sub-treatments comprises of four N fertigation levels (0,60,120,180 kg N/ha). Drip irrigation scheduling and N-fertigation levels significantly affected the rice grain yields in *kharif,* 2012 and 2013 seasons. Whereas, during *kharif,* 2014 nitrogen fertigation levels only significantly influenced the grain yield of aerobic rice. Irrigation equivalent to 150% pan evaporation replenishment produced significantly higher grain yield over 100% pan evaporation replenishment. Each higher level of nitrogen significantly enhanced the grain yield of rice up to 120 kg N/ha. The seasonal water use (ETc) in drip irrigated aerobic rice ranged from 729 to 979, 617 to 1108 and 504 to 1008 mm in *kharif*, 2012,2013 and 2014, respectively under different drip irrigation schedules with mean water productivity values ranges between 0.35 to 0.49 kg $m^{-3}$ among drip irrigation regimes.

**Keywords:** Climate change, aerobic rice, drip irrigation, fertigation, water productivity.

## 1. INTRODUCTION

Rice an important staple food crop in the world and most widely grown under irrigation with seasonal water needs ranging between 1650 to 3000 mm depending upon soil and climatic conditions (Tuong and Bouman, 2003; Lampayan and Bouman, 2005). To produce 1 kg of rough (unmilled) rice on an average 2500 mm of water is needed (Bouman, 2009). In Asia, more than 80% of the developed freshwater resources are used for irrigation purposes and about half of this is used for rice production alone (Dawe et al. 1998). Until recently, this amount of water has been taken for granted, but now the global “water crisis” threatens the sustainability of irrigated rice production as a result of decreasing water quality (chemical pollution, salinization), decreasing water resources (e.g., falling groundwater tables, silting of reservoirs),and increased competition from other sectors such as urban and industrial users (Belder *et al*. 2004; Bouman, 2007). On the other hand, to keep pace

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with the population growth and income induced demand for food, it is estimated that rice production has to be increased by 56% over the next 30 years (IRRI, 1997). Therefore, it is essential to 'produce more rice with less water' (Guerra *et al.* 1998; Bouman, 2007). Main driving force behind aerobic rice is economic water use. Scientists are now taking on the challenging task of developing rice production systems that can cope with water scarcity and looking for ways to decrease water use in rice production. The labor use is also saved in aerobic rice because more labor is required for land preparation such as puddling, transplanting, and irrigation activities in flooded rice (Wang *et al*. 2002).

A fundamentally different approach to reduce water inputs in rice is to grow the crop like an irrigated-dry crop, such as wheat or corn using modern irrigation systems. Aerobic rice crop is grown in non-puddled, non-saturated aerobic soil with an optimally balanced soil water-air conditions in the rhizosphere. Aerobic rice cultivation is targeted for irrigated areas where water has become so scarce or expensive that lowland rice cannot be maintained anymore. Rainfed areas where rainfall is insufficient to allow lowland rice production, but sufficient for aerobic rice. Irrigation scheduling in ET based approach is the water applied equivalent to replenish the soil water content in the root zone back to the field capacity during each irrigation event after it has reached a certain lower permissible threshold. Thus the field water supply matches the evapotranspiration requirements of the rice crop. Nitrogen is an important nutrient element in the soil for rice crop but unlike low land puddle soil, the nitrogen availability in aerobic conditions is low.There are reports that aerobic rice responds to nitrogen application up to 100 (Danial and Wahab, 1994), 150 (Reddy *et al.*1993 and Maheswari *et al.* 2007), 180 kg/ha (Ghobrial.,1983). Zhang *et al*. (2009) reported that there was no interaction effect between N rates and water management. Limited research has been done on optimizing nutrient management to produce high yield of aerobic rice. Hence, a field study was conducted to evaluate the variable surface drip irrigation schedules along with the N levles for optimaziation of consumptive water use and N feertigation levels for aerobic rice cultivation in the semi-arid region of India.

## 2. MATERIALS AND METHODS

A field experiment was conducted continuously for three seasons during *kharif*, 2012, 2013 and 2014 at Water Technology Centre, College Farm, Prof.Jayashankar Telangana State Agricultural University (Formerly part of Acharya N.G. Ranga Agricultural University), Rajendranagar, Hyderabad). Geographically the farm is located at 78°24'43" E–Longitude and 17°19'16" N–Latitude at an altitude of 542.6 m amsl. The soil was sandy clay loam in texture, alkaline in reaction (pH 8.0) and non-saline with C1 class (EC = 0.7 dS/m). The soil was low in organic carbon (0.15) and available nitrogen (257 kg/ha), medium in available $P_2O_5$ (45 kg/ha) and $K_2O$ (312 kg/ha).The average soil bulk density and infiltration rate was 1.48 g/cm$^3$ and 24 mm/hour, respectively. Likewise the average volumetric soil water content at field capacity (0.33 bars) and permanent wilting point (15 bars) was 0.284 cm3/cm3 and 0.161 cm3/cm3, respectively. Whereas the available soil moisture estimated was 110.8 mm/m depth of soil. The drip system was installed as per the statistical design in the field. The drip lateral used was integral pressure compensated dripper line spaced at 0.8 m with each dripper line feeding four rice crop rows (Fig.1).The emitter spacing was 0.4 m with an emitter flow rate of 2 LPH. The resultant application rate was 6.25 mm/hr. The rice experiment was laid out in split plot design with 3 replications.

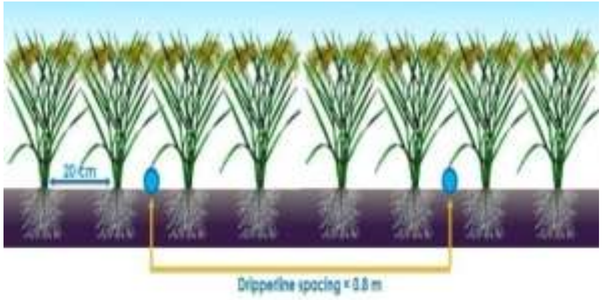


**Figure 1.** Dripper line location in drip irrigated aerobic rice

There were three treatments consisted of drip irrigation schedules *viz.,* Irrigation at evaporation (from USWB Class A Pan evaporimeter) replenishment of 100, 150 and 200 % in main-plots. While four nitrogen (N) fertigation levels *viz.,* 0 N/ha (control), 60, 120 and 180 kg N/ha were allocated in the sub-plots. A medium duration (125-130 days) rice variety MTU – 1010 was sown in all the three years using a seed rate of 80 kg/ha in solid rows at 20 cm apart. The recommended $P_2O_5$ @ 60 kg/ha in the form of Single Super Phosphate along with Zinc sulphate @50 kg/ha was applied uniformly to all the plots as basal dose during the last ploughing. Likewise the recommended $K_2O$ @ 40 kg/ha was fertigated uniformly to all plots along with N as per the treatments at weekly intervals using water soluble fertilizers viz*.,* urea and sulphate of potash. The fertigation commenced from 15 DAS and continued up to 90 DAS. A pre-emergence application of herbicide (Pendimethalin @ 3.0 l/ha) was sprayed 2 DAS onorder to control the easrly emerging weeds followed by hand weeding at 30 DAS. Iron deficiency noticed was corrected by foliar application (3 times at weekly intervals) of ferrous sulphate @ 2%. Direct dry seed sowing was adopted without any nursery & transplanting in aerobic rice. Further, a transplanted conventional flood irrigated control rice plot (non-replicated) with same variety was also maintained to compare the water input use. Irrigation water was scheduled to each treatmental plot at a pre-determined pan evaporation replenishment factor after adjusting the effective precipitation received (CropWat) and the amount of water discharged through drip was measured through water meter attached at drip irrigation system control unit. The water productivity (kg $m^{-3}$ of water) was calculated by following equation.

$$\mathbf{WP = Y/ WA_{(IR+ER)}}$$

Where

Y = Grain yield (kg/ ha)
WA ( total water used in $m^3$) = IR ( irrigation ) + ER (effective rainfall)

The seasonal rainfall received during the crop period was 584,703 and 433 mm as against the cumulative pan evaporation of 479,610 and 597 mm in 2012, 2013 and 2014, respectively.The data collected in the present experiment on rice yield was analyzed statistically and where ever the treatment differences were found significant (F test), the critical difference was calculated at 5% probability. The mean yield data obtained at different drip irrigation regimes and N levels were subjected to regression analysis to find out the optimum consumptive water use and N dose for drip fertigated aerobic rice.

Table 1. Grain yeld and harvest index of aerobic rice as influenced by drip rrigation schedules and N- fertigation levels

| Treatments | Grain yield(kg/ha) | | | | Harvest Index (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | Mean | 2012 | 2013 | 2014 | Mean |
| Main treatments (Drip irrigation schedules) | | | | | | | | |
| $I_1$ -1.0 Epan | 2991 | 2903 | 2968 | 2954 | 35.8 | 30.4 | 34.3 | 33.5 |
| $I_2$ - 1.5Epan | 3978 | 3907 | 3099 | 3661 | 41.1 | 36.0 | 33.6 | 36.9 |
| | 3720 | 3876 | 3480 | 3692 | 38.6 | 35.7 | 35.7 | 36.6 |
| SEm | 109 | 157 | 210 | - | - | - | - | - |
| CD(%) | 429 | 616 | NS | - | - | - | - | - |
| Sub treatments (N –Levels-kg/ha) | | | | | | | | |
| $N_0$ | 2052 | 3238 | 2460 | 2583 | 30.6 | 35.9 | 32.1 | 32.9 |
| $N_{60}$ | 3702 | 3377 | 2832 | 3304 | 41.6 | 32.1 | 32.1 | 35.3 |
| $N_{120}$ | 4360 | 3911 | 3879 | 4050 | 40.4 | 35.1 | 37.2 | 37.6 |
| $N_{180}$ | 4137 | 3722 | 3562 | 3807 | 39.6 | 33.8 | 35.8 | 36.4 |
| SEm | 84 | 151 | 127 | - | - | - | - | - |
| CD (5%) | 250 | 449 | 378 | - | - | - | - | - |
| Interaction : N levels at same levels of irrigation schedules | | | | | | | | |
| SEm | ** | 185 | 167 | | | | | |
| C.D (5%) | | NS | NS | | | | | |

## 3. RESULTS AND DISCUSSION

### 3.1 Grain yield

Grain yield of aerobic rice was significantly influenced by drip irrigation levels and N-fertigation levles in all the years of study except in 2014 the grain yield was not influenced by drip irrigation schedules(Table-1). Irrigation equivalent to 200% pan evaporation replenishment ($I_{2.0}$) produced significantly higher grain yield over 100% pan evaporation replenishment ($I_{1.0}$). Further, it was noticed that application of water equivalent to 150% pan evaporation replenishment ($I_{1.5}$) through drip produced the grain yield statistically at par grain yield as compared to 200% pan evaporation replenishment ($I_{2.0}$). Whereas, each higher level of nitrogen fertigation significantly enhanced the grain yield of rice up to 120 kg N/ha. Application of N at 180 kg N/ha did not prove to be advantageous and it decreased the yield marginally in comparison to 120 kg/ N /ha but the decrease was not statically significant. Among the three years of study, 2014 was more dryer as a result of less rainfall and higher daily evaporation rate than that of 2012 and this was reflected in the reduction of grain yield. McCauley (1990) recorded 20% yield reduction in direct

seeded rice cultivars under sprinkler irrigation but pressurized irrigation systems (sprinkler, surface & subsurface drip) have the potential to increase WUE by providing water to match crop requirements, reducing runoff & deep drainage losses.

Whereas, in respect of interaction effect (I x N) it was found significant in the first year of study (Table-2) only. Irrigation equivalent to 150% pan evaporation replenishment in conjunction with 120 kg N/ha registered significantly higher grain yield over other I x N treatment combinations. Further, it was noticed that at higher irrigation level of 200% pan evaporation replenishment, application of N beyond 120/ha was detrimental to yield. Subsurface drip irrigation improved mean grain yield reduction of rice from 24.2 per cent as observed with surface irrigation using a limited water supply, to 12.4 per cent besides higher WP and NUE (Vanitha,2011). Sub-surface drip system having an added advantage of lesser methane (CH4) emission fetching higher 'carbon credits' to the aerobic rice farmers.

## 3.2 Harvest Index

Harvest index has been shown to be a variable factor in crop production, and in many situations, it is closely associated with WUE and grain yield. Proper crop and water management holds great promise to enhance harvest index and consequently, achieve the dual goal of increasing grain production and saving water. A water and nitrogen management system that could increase growth rate during grain growth enhance the remobilization of assimilates from vegetative tissues to grains during the grain-filling period usually leads to a higher HI within a crop. In the present study,its once again proved that the higher HI noticed (Table-2) at application of water through drip irrigation equivalent to 150% pan evaporation replenishment ($I_{1.5}$) over either 100% pan evaporation replenishment ($I_{1.0}$) or 200% pan evaporation replenishment ($I_{2.0}$) could be due to realization of comparatively higher grain yield at moderate water and N application(120 kg ha$^{-1}$). The HI increases with each incrementak dose of N from 0 to 120 kg ha$^{-1}$ and threreafter it shown a declining trend.

## 3.3 Water Productivity

Water productivity (weight of produce per unit volume of water used) should be used as an indicator to compare different water saving systems/technologies in terms of their effective use of water for food production. The water productivity represents grain of rice produced per unit amount of water consumed.Typical water productivity (WP) values for flood irrigated rice crop were reported to

range from 0.2 to 0.4 (Bouman and Tuong, 2001) but in the present study (Table 3), the water productivity of aerobic rice was enhanced (0.35 – 0.49 kg/m$^3$) over conventional flood irrigated rice ( 0.32 kg/m$^3$). Thus, shifting from conventional flooded systems to aerobic rice under surface drip irrigation reduced the water requirement by 38- 63 % . The water requirement was down by 50% by reducing seepage, percolation and evaporation losses in view of ET based irrigation scheduling in aerobic rice (Medley & Wilson, 2008).

Table 2.Interaction effect of drip irrigation schedules and N- fertigation on aerobic rice grain yield during *kharif,*2012.

| N-fertigation levels | Drip irrigation schedules | | |
|---|---|---|---|
| | $I_{1.0}$(100% Epan) | $I_{1.5}$(150% Epan) | $I_{2.0}$(200% Epan) |
| $N_0$ (No Nitrogen) | 1960 | 2156 | 2042 |
| $N_1$(60 kg/ha) | 2979 | 3980 | 4148 |
| $N_2$(120 kg/ha) | 3690 | 4842 | 4550 |
| $N_3$(180 kg/ha) | 3337 | 4933 | 4142 |
| I x N Interaction effect | | SEm ± | C.D(5%) |
| N at same level of irrigation | | 146 | 434 |
| Irrigation at same or different level of N | | 167 | 565 |

Table 3. Water requirement and water productivity of aerobic rice by evapotranspiration based drip irrigation at Hyderabad,India.

| Irrigation regimes | Total Water used (mm)* | | | | Water Productivity (kg/m$^3$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | Mean | 2012 | 2013 | 2014 | Mean |
| $I_{1.0}$-Epan | 729 | 617 | 504 | 617 | 0.41 | 0.47 | 0.58 | 0.49 |
| $I_{1.5}$-Epan | 848 | 800 | 756 | 801 | 0.46 | 0.48 | 0.40 | 0.45 |
| $I_{2.0}$- Epan | 979 | 1108 | 1008 | 1032 | 0.38 | 0.34 | 0.34 | 0.35 |
| Continous submergence( Transplanted) | 1650 | 1681 | 1631 | 1654 | 0.33 | 0.32 | 0.30 | 0.32 |

*An amount of 479, 535 and 302 mm of effective rainfall was included during 2012, 2013 and 2014, respectively.

The variations in crop water consumption in different years during the study period may be due to varied amounts of rainfall received and daily evaporation prevailed. An thThe performance of aerobic rice during first and second year of study was superior than that of 2014 because of prevailing dry climate. By reducing water use during land preparation and limiting seepage, percolation, and evaporation,aerobic rice had about 51% lower total water use and 32-88% higher water productivity, expressed as gram of grain per kilogram of water, than flooded rice (Bouman *et al*. 2005).

### 3.4 Optimum consumptive water use

The rice yield response to water was established by subjecting the mean grain yield and ETc data under different irrigation treatments to regression analysis. The response was best explained by quadratic function with a total explained variation of 99 %. The rice grain yield increased with increase in water use, but the increase in grain yield was not proportional to the ETc (Figure 2). The maximum grain yield (Ymax) was bracketed within the tested water use levels. The predicted maximum rice grain yield (Ymax) of 3800 kg/ha was obtained with 920 mm/ha of water use (ETc).

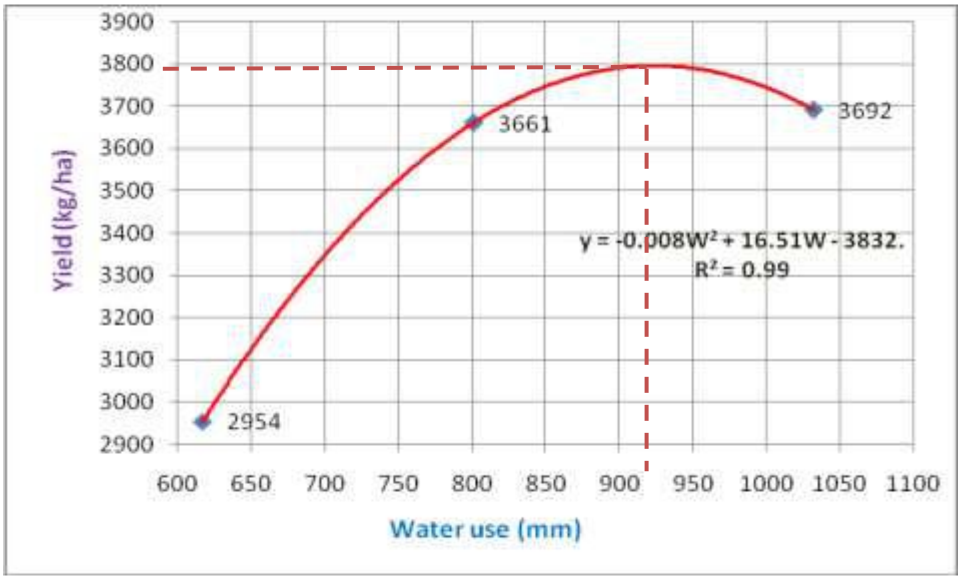


**Figure 2.** Response of drip irrigated rice grain yield to water levels

### 3.5 Optimum N rate

The rice yield response to water application was establish by subjecting the mean grain yield and applied N rates data under different nitrogen fertigation treatments to regression analysis. The response was best explained by quadratic function with a total explained variation of 95%. The rice grain yield increased with increase in nitrogen rates, but the increase in grain yield was not proportional to the nitrogen doses applied (Figure 3). The maximum grain yield (Ymax) was bracketed within the tested N-fertigation levels. The predicted maximum rice grain yield (Ymax) of 3950 kg/ha was obtained with 140 kg N/ha.

## 4. CONCLUSIONS

The three years study results clearly revealed that drip irrigation scheduling and N-fertigation significantly enhanced the aerobic rice grain yields. Irrigation equivalent to 150% pan evaporation replenishment ($I_{1.5}$) and nitrogen fertigation at 120 kg N/ha produced significantly higher rice grain yield. Surface drip irrigation scheduling based on evaporation replenishment factor in aerobic rice realized higher water productivity with considerable water saving over conventional flood irrigated rice. Further, the predicted maximum grain yield levels were at 920 mm of crop ET and 140 kg N/ha among different drip irrigation and N fertigation levels tested. Aerobic rice technology is better remedy for future climate change under drought condition with lesser green house gas (GHG) emission.

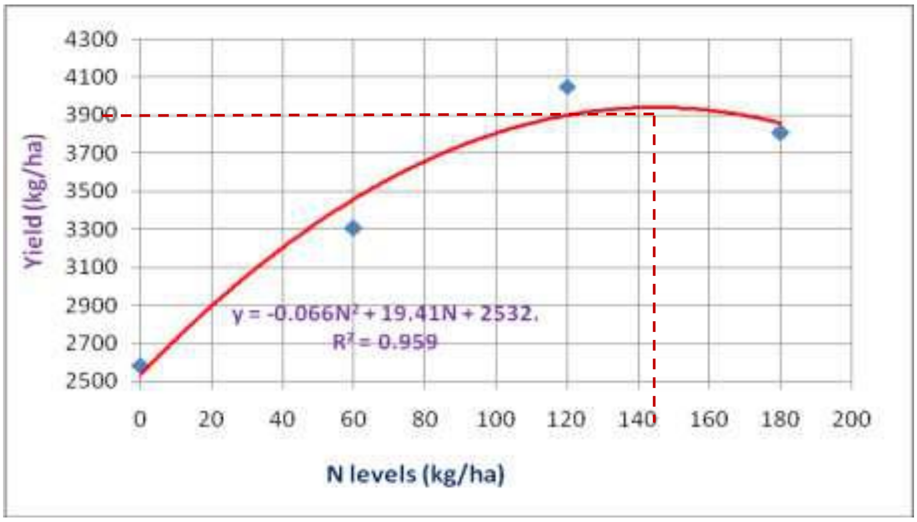


**Figure 3.** Response of drip irrigated rice grain yield to nitrogen levels

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