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# Water Saving Strategy in Rice by Alternate Wetting and Drying Technology

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**ABSTRACT**

A field experiment was conducted during 2016 and 2017 at Instructional-cum-Research (ICR) Farm of Assam Agricultural University, Jorhat to work out the optimum irrigation scheduling on the transplanted autumn rice with alternate wetting and drying technology. In both the years, irrigation at 15 cm depletion of water from soil surface gave the highest grain yield and straw yield. The growth characteristics in terms of plant height, number of tillers per hill, CGR and RGR and yield attributing characteristics like number of effective tillers per hill, length of panicle, number of grains per panicle recorded the highest values under irrigation at 15 cm depletion of soil surface. The treatment also recorded the highest Crop Water Use Efficiency during both the years. The benefit: cost ratio was also found to be highest under this treatment.

## Introduction

In Assam, rice occupies about 2.54 million hectares *i.e.*, two-third of the gross cropped area of 4.16 million hectares (Anonymous, 2016) It contributes 96 per cent to the total food grain production of the state. The agro-climatic variation of the state is mainly responsible for the classification of rice growing seasons- *sali* (winter rice), *boro* (summer rice) and *ahu* (autumn rice), which is based on the time of harvest. Among these, *ahu* rice is photoperiod insensitive, early maturing and grown as direct seeded crop as rainfed or transplanted crop with irrigation. Irrigation strongly influences the rice yield. With current practices, the rice crop consumes large quantity of irrigation water, ranging between 1500 and 3000 mm (Sharma *et al.*, 2002; Singh *et al.*, 2002). Rice is considered as one of the most important factor for fall in water table in central Punjab of India (Singh, 2006). Recent water shortages in reservoirs causes problems as insufficient water and fallow rice fields; therefore, comparing irrigation water requirements and crop production of paddy fields using a technique that differs from the conventional flood irrigation method is important (Kuo, 2014). Therefore, it is felt that there is a need to save water in rice cultivation, which led to development of alternative methods of cultivation *i.e*., alternate wetting and drying (AWD), Alternate wetting and drying is such a water saving technology in rice production that can reduce the number of irrigations as compared to farmers' conventional practice, thereby lowering irrigation water consumption by 23% (Bouman and Tuong, 2001) to 38% (Lampayan *et al.,* 2015).

## Materials and Methods

A field experiment was conducted for two years (2016 and 2017) at Instructional-Cum-Research (ICR) Farm of Assam Agricultural University, Jorhat, India during the *ahu* season in transplanted autumn rice based on the alternate wetting and drying technology of IRRI to work out the irrigation scheduling in the crop and to find out its growth, development and yield of the crop under this irrigation technology. The climatic condition of Jorhat is sub-tropical humid with hot summer and cold winter. Normally, monsoon starts from the month of June and continues up to the month of September with the occurrence of low pre-monsoon showers from mid March. During 2016 and 2017, the total amount of rainfall received was 1106.10 mm and 698 mm with a maximum average weekly rainfall of 258.6 mm and 115.9 mm, respectively. The weekly mean maximum temperature ranged from 17.7 to 27.8 °C during 2016 and 14.9 to 26.6 °C during 2017. Weekly mean minimum temperature ranged from 16.9 to 26.7 °C and 14.4 to 26.2 °C during 2016 and 2017, respectively. The weekly average relative humidity ranged from 88.1 to 97.0% during the morning hours and 55.8 to 90.7 % in the evening hours during 2016. During 2017, morning and evening relative humidity ranged from 90.4 to 96.7% and 60 to 82.1%, respectively. The experiment was laid out in randomized block design (RBD) and replicated thrice. The treatments consisted of eight irrigation regimes *viz.*, irrigation at 5 cm depletion of water from soil surface ($T_1$), irrigation at 10 cm depletion of water from soil surface ($T_2$), irrigation at 15 cm depletion of water from soil surface ($T_3$), irrigation at 20 cm depletion of water from soil surface ($T_4$), irrigation at 25 cm depletion of water from soil surface ($T_5$), irrigation at 30 cm depletion of water from soil surface ($T_6$), irrigation at 3 days after disappearance of ponded water ($T_7$) and continuous flooding ($T_8$). All plots received N-$P_2O_5$-$K_2O$ at recommended dose of 40-20-20 kg/ha in the form of Urea, Single Super Phosphate (SSP) and Muriate of Potash (MOP), respectively, where N was applied in 2 split doses. Half N and full $P_2O_5$ and $K_2O$ were applied at final puddling. Remaining half N was applied at panicle initiation stage. The rice variety "Dishang" was sown on 23$^{rd}$ February, transplanted on 15$^{th}$ March and harvested on 18$^{th}$ June during 2016 whereas during 2017, it was sown on 24$^{th}$ February, transplanted on 22$^{nd}$ March and harvested on 19$^{th}$ June. The soil of the experimental plots were silty loam in texture, acidic in reaction (pH 5.5), medium in organic carbon (0.63%), low in low in alkaline $KMnO_4$ extractable N (171.31 kg/ha), medium in Brays I P (10.1 kg/ha) and medium in 1 N ammonium acetate extractable K (212.1 kg/ha). The field capacity was found to be 27.45% while permanent wilting point was 7.70%. For chemical analysis, plant samples were oven dried at 65°C to a constant weight and grounded to reduce the material to a fineness suitable size by using a mechanical grinder. Samples were digested in diacid mixture of $H_2SO_4$ and $HClO_4$ in the ratio of 9: 1 for nutrient N estimation. P and K were estimated by Vanadomolybdate method and flame photometer method respectively. The nutrient uptake (kg/ha) by the crop was calculated by multiplying the grain yield per plot (kg/ha) with the nutrient content of the grain (%). The data were analyzed statistically and the mean differences among the treatment means were evaluated by the least significance difference (LSD) at 5% level of probability (Sarma, 2016). For economic analysis, all input costs including the cost for lease of land and interest on running capital were considered for computing the cost of production. Leaf Area Index (LAI), Leaf Area Duration (LAD), Crop Growth Rate (CGR) and Relative Growth Rate (RGR) were calculated as per standard formula.

## Results and Discussion

### Effect of irrigation scheduling on growth parameters

The study revealed that the morphological characteristics of the plant including plant height, LAI, LAD, CGR, RGR showed significant differences among the treatments (Table 1, Figs. 1 and 2). The highest plant height was recorded by 15 cm depletion of water from soil surface ($T_3$) which was at par with depletion of 5 cm ($T_1$) and 10 cm ($T_2$) irrigation water, irrigation at 3 DADPW ($T_7$) and continuous flooding ($T_8$). Similarly, 15 cm depletion of water from soil surface ($T_3$) being at par with depletion of 5 cm ($T_1$) and 10 cm ($T_2$) of irrigation water, irrigation at 3 DADPW ($T_7$) and continuous flooding ($T_8$) recorded the highest LAD. The lowest plant height and LAD were recorded by 5 cm irrigation at 30 cm depletion of water from soil surface ($T_6$).

CGR was found to increase statistically from 0-30 DAT to 30-60 DAT and then decreased at 60-90 DAT. However, RGR was highest at 0-30 DAT and gradually decreased at 30-60 DAT to 60-90 DAT. All the growth characteristics recorded the highest values under irrigation at 15 cm depletion of water from soil surface ($T_3$). Better growth parameters under these treatments could be due to improved root growth with alternate wetting and drying (AWD) enabling greater access to water and nutrients at depth in the soil profile which is in line with the earlier findings of Yang *et al.*, (2009).

### Effect of irrigation scheduling on yield attributing characters and yield

In both the years, yield attributing characters like effective tillers per hill, panicle length and number of grains per panicle were found to be highest under irrigation at 15 cm depletion of water from soil surface ($T_3$) (Table 2). However, depletion of 5 cm ($T_1$) and 10 cm ($T_2$) of irrigation water and irrigation at 3 DADPW ($T_7$) were at par with $T_3$. However, 1000 seed weight and harvest index were found to be non-significant. AWD is beneficial in maintaining yield attributes and grain yield of rice were also reported by Bouman and Tuong (2001).

In both the years, the highest grain and straw yield was obtained from irrigation at 15 cm depletion of water from soil surface ($T_3$) which was followed by irrigation at 10 cm deletion of water from soil surface ($T_2$) and irrigation at 5 cm depletion of water from soil surface ($T_1$) and irrigation at 3 DADPW, all being at par. Yang *et al.*, (2017) reported that increases in grain yield under moderate AWD were due mainly to improved canopy structure and root growth, elevated hormonal levels, in particular increases in abscisic acid levels during soil drying and cytokinin levels during rewatering and enhanced carbon remobilization from vegetative tissues to grain.

### Effect of irrigation scheduling on water use and water use efficiency

Lowest irrigation water was used in irrigation at 30 cm depletion of water from soil surface ($T_6$) followed by irrigation at 25 cm ($T_5$), 20 cm ($T_4$) and 15 cm ($T_3$) depletion of water from soil surface (Table 3).

**Table.1** Plant height, LAI and LAD as influenced by irrigation scheduling

| Treatment | Plant height at harvest (cm) | | LAI | | | | LAD (days) | |
|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | 30 DAT | | 60 DAT | | | |
| | | | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| $T_1$ | 90.3 | 91.1 | 1.60 | 1.71 | 4.32 | 4.61 | 213.0 | 225.0 |
| $T_2$ | 90.4 | 91.6 | 1.65 | 1.77 | 4.81 | 5.11 | 231.2 | 243.8 |
| $T_3$ | 91.2 | 91.9 | 1.76 | 1.89 | 4.93 | 5.25 | 240.2 | 253.7 |
| $T_4$ | 81.2 | 87.3 | 1.45 | 1.52 | 4.11 | 4.29 | 202.8 | 210.3 |
| $T_5$ | 81.1 | 82.0 | 1.31 | 1.39 | 3.85 | 4.01 | 186.3 | 193.5 |
| $T_6$ | 79.8 | 80.1 | 1.25 | 1.35 | 3.61 | 3.89 | 171.3 | 182.7 |
| $T_7$ | 90.4 | 91.7 | 1.73 | 1.82 | 4.77 | 5.21 | 232.1 | 248.0 |
| $T_8$ | 89.8 | 90.1 | 1.37 | 1.47 | 4.14 | 4.42 | 199.4 | 210.8 |
| SEm ± | 2.8 | 2.7 | 0.08 | 0.10 | 0.23 | 0.27 | 10.8 | 11.9 |
| CD(P=0.05) | 8.5 | 8.1 | 0.25 | 0.31 | 0.70 | 0.85 | 32.8 | 36.1 |

**Table.2** Yield attributing characters of rice as influenced by irrigation scheduling

| Treatment | Effective tillers/hill | | Length of panicle (cm) | | Number of grains/ panicle | | Test weight (g) | | Grain yield (t/ha) | | Straw yield (t/ha) | | Harvest Index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| $T_1$ | 7.7 | 7.9 | 23.0 | 24.1 | 74.0 | 78.7 | 23.3 | 23.0 | 3.91 | 4.24 | 5.97 | 6.89 | 0.39 | 0.38 |
| $T_2$ | 7.9 | 8.1 | 23.7 | 24.3 | 75.2 | 79.4 | 23.0 | 23.0 | 4.19 | 4.42 | 6.21 | 6.97 | 0.40 | 0.39 |
| $T_3$ | 8.0 | 8.4 | 23.9 | 24.6 | 76.9 | 80.0 | 23.3 | 23.0 | 4.28 | 4.52 | 6.32 | 7.07 | 0.41 | 0.39 |
| $T_4$ | 7.1 | 7.5 | 21.3 | 22.3 | 67.2 | 71.9 | 22.7 | 22.9 | 3.51 | 3.89 | 5.29 | 6.25 | 0.40 | 0.38 |
| $T_5$ | 7.1 | 7.3 | 21.0 | 22.0 | 66.3 | 71.6 | 23.0 | 22.9 | 3.38 | 3.85 | 5.22 | 6.20 | 0.40 | 0.38 |
| $T_6$ | 7.0 | 7.2 | 20.3 | 21.4 | 65.2 | 69.1 | 22.7 | 22.9 | 3.31 | 3.52 | 5.09 | 6.00 | 0.39 | 0.37 |
| $T_7$ | 7.7 | 8.1 | 23.3 | 24.2 | 75.0 | 75.7 | 22.7 | 22.9 | 4.02 | 4.26 | 6.11 | 6.75 | 0.40 | 0.39 |
| $T_8$ | 6.9 | 7.1 | 23.0 | 24.0 | 75.0 | 79.6 | 22.7 | 23.0 | 3.71 | 4.01 | 6.11 | 6.65 | 0.38 | 0.38 |
| SEm ± | 0.2 | 0.2 | 0.8 | 0.7 | 2.9 | 2.6 | 0.9 | 0.4 | 0.16 | 0.20 | 0.34 | 0.33 | 0.03 | 0.04 |
| CD | 0.7 | 0.7 | 2.5 | 2.1 | 8.7 | 7.9 | NS | NS | 0.49 | 0.59 | 0.80 | 0.78 | NS | NS |

**Table.3** Yield of rice as influenced by irrigation scheduling

| Treatment | Irrigation water used (cm) | | Irrigation WUE (kg/ha-cm) | | Crop WUE (kg/ha-cm) | | Total nutrient uptake (kg/ha) | | | | | | Net Return (₹) | | B : C Ratio | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | N | | P | | K | | | | | |
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| $T_1$ | 60.0 | 65.0 | 65.2 | 65.2 | 138.3 | 142.8 | 102.2 | 104.2 | 22.5 | 24.4 | 101.5 | 106.4 | 34091 | 39000 | 2.24 | 2.39 |
| $T_2$ | 58.0 | 60.0 | 72.2 | 73.7 | 148.4 | 149.1 | 107.8 | 109.7 | 24.3 | 26.6 | 103.6 | 107.6 | 38561 | 42241 | 2.41 | 2.53 |
| $T_3$ | 53.5 | 55.0 | 80.0 | 82.2 | 151.2 | 152.1 | 111.7 | 115.2 | 24.9 | 27.0 | 116.6 | 119.2 | 40466 | 44290 | 2.50 | 2.64 |
| $T_4$ | 51.5 | 50.0 | 68.2 | 77.8 | 125.0 | 131.9 | 85.1 | 87.3 | 20.3 | 21.4 | 86.9 | 90.1 | 28601 | 34930 | 2.07 | 2.32 |
| $T_5$ | 45.0 | 45.0 | 75.1 | 85.6 | 121.9 | 132.2 | 78.7 | 81.3 | 20.1 | 21.1 | 86.1 | 89.8 | 27266 | 34805 | 2.05 | 2.34 |
| $T_6$ | 38.5 | 40.0 | 86.0 | 88.0 | 118.7 | 120.2 | 76.7 | 80.4 | 18.7 | 20.3 | 84.3 | 90.2 | 26800 | 30256 | 2.06 | 2.18 |
| $T_7$ | 56.5 | 60.0 | 71.2 | 71.0 | 141.3 | 142.6 | 102.4 | 104.8 | 24.0 | 25.5 | 113.4 | 110.6 | 36160 | 39731 | 2.33 | 2.44 |
| $T_8$ | 90.0 | 95.0 | 41.2 | 42.2 | 127.1 | 130.8 | 98.4 | 100.3 | 23.3 | 25.9 | 109.0 | 109.2 | 28160 | 32431 | 1.92 | 2.04 |
| SEm ± | - | - | - | - | - | - | 5.7 | 5.9 | 0.9 | 1.1 | 5.2 | 5.5 | - | - | - | - |
| CD | - | - | - | - | - | - | 17.3 | 16.5 | 2.7 | 2.6 | 15.6 | 14.6 | - | - | - | - |

**Fig.1** CGR at 30 days interval as influenced by irrigation scheduling

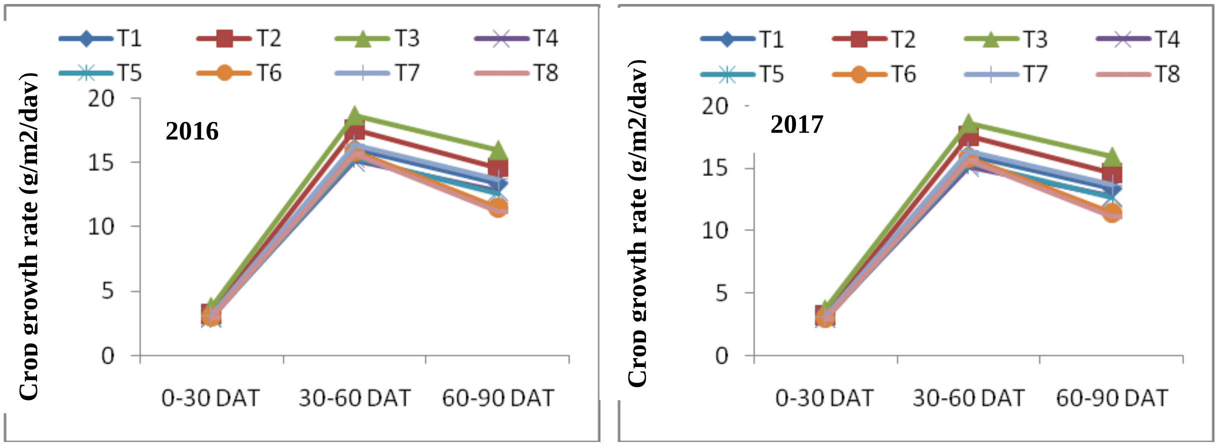
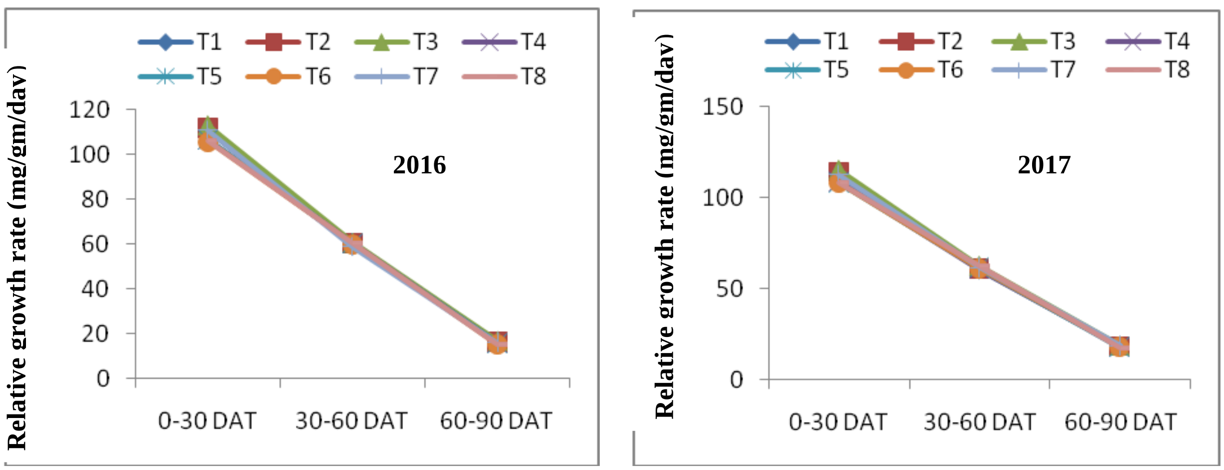



**Fig.2** RGR at 30 days interval as influenced by irrigation scheduling




The highest water was used under continuous flooding ($T_8$). Irrigation at 30 cm depletion of water from soil surface ($T_6$) also recorded the highest irrigation water use efficiency and was closely followed by irrigation at 15 cm depletion of water from soil surface ($T_3$). However, irrigation at 15 cm depletion of water from soil surface ($T_3$) recorded the highest water use efficiency. The lowest irrigation water use efficiency and water use efficiency were recorded under continuous flooding. Higher consumptive use of water with continuous flooding might be due to the fact that under more frequent wetting cycle, evaporation was higher due to the availability of more water as compared to the crop irrigated at wider interval. These findings are in general agreement with those of Singh *et al.*, (2001); Yadav *et al.*, (2011) and Sarma and Das (2013). Thus, there was an increase in yield with water saving of 16.92% in 2016 and 21.85% in 2017 over continuous flooding.

## Effect of irrigation scheduling on nutrient uptake

The effect of different irrigation treatments on nitrogen, phosphorus and potassium uptake by grain and straw was found to be significant (Table 3). Irrigation at 15 cm depletion of water from soil surface ($T_3$) being at par with depletion of 5 cm ($T_1$) and 10 cm ($T_2$) water from soil surface, irrigation at 3 DADPW ($T_7$) and continuous flooding ($T_8$) recorded the highest N, P and K uptake. The increase in nutrient uptake could be attributed to well-developed root system under alternate wetting and drying and availability of soil held nutrients to the rice plant resulting in better absorption of water and nutrients that increased the dry matter as well as higher N, P and K concentration in plants. These findings are in general agreement with those of Tuong and Bouman (2002), Shimono and Bunce (2009) and Somaweera *et al.*, (2016).

## Effect of irrigation scheduling on economics of rice

Irrigation at 15 cm depletion of water from soil surface ($T_3$) recorded the highest net return (₹ 40,466 and ₹ 44,290) and Benefit-Cost ratio (2.50 and 2.64) during both the years (Table 3). It was closely followed by irrigation at 10 cm depletion of water from soil surface (₹ 38,562; ₹ 42,241 and 2.41; 2.53) and 3 DADPW (₹36,160; ₹ 39,731and 2.33; 2.44). The lowest net return was recorded under irrigation at 30 cm depletion of water from soil surface (₹ 26,800; ₹ 30,256) while the lowest Benefit-Cost ratio was observed under continuous flooding (1.92; 2.04). Nalley *et al.*, (2015) also investigated the economic viability of different AWD treatments and found the lowest profit in the treatment with highest water productivity.

Thus, it could be concluded that in early *ahu* rice, crop should be irrigated at 15 cm depletion of water from the soil surface.

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