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# Water productivity and nutrient uptake of direct seeded early *Ahu* rice under medium land situation

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## Abstract
A field experiment was carried out at Assam Agricultural University, Jorhat to find out water productivity and nutrient uptake of direct seeded early *ahu* rice under medium land situation. The treatments consisted of 4 irrigation regimes *viz.* irrigation at 80% available water till onset of pre-monsoon rain ($I_1$), irrigation at 70% available water till onset of pre-monsoon rain ($I_2$), irrigation at 60% available water till onset of pre-monsoon rain ($I_3$) and rainfed ($I_4$) as main plot and 3 nutrient management treatments *viz.* full P as basal + ½ N and ½ K at 20 DAS + ½ N and ½ K at 40 DAS ($N_1$), full P as basal, $^1/_3$ N and $^1/_3$ K as basal + $^1/_3$ N and $^1/_3$ K at 20 DAS + $^1/_3$ N and $^1/_3$ K at 40 DAS ($N_2$) and full P as basal, ½ N and ½ K as basal + ¼ N and ¼ K at 20 DAS + ¼ N and ¼ K at 40 DAS ($N_3$) as sub plot and control (transplanted early ahu rice with recommended water and fertilizer management practices). Experimental findings revealed that irrigation at 80% available water till onset of pre monsoon rain ($I_1$) recorded the highest nutrient (N, P and K) uptake and water productivity of the crop. Among the nutrient management treatments, the highest nutrient uptake and water productivity were recorded under full P as basal + ½ N and ½ K at 20 DAS + ½ N and ½ K at 40 DAS ($N_1$). The direct seeded rice recorded lower water use and higher water productivity and nutrient balance than transplanted crop.

**Keywords:** direct seeded rice, nutrient balance, nutrient uptake water productivity

## Introduction
Rice (*Oryza sativa* L.) is the leading cereal of the world (Ashraf *et al.*, 2006) [1] and more than half of the human race depend on rice for their daily sustenance (Chauhan and Johnson, 2011) [2]. It is the source for 35–80% of total calorie intake of Asian population (IRRI, 1997) [3]. India is the second largest producer of rice next to China and accounts for 45% of food grain production in the country (Singh *et al.*, 2013) [4]. The most common methods of rice crop establishment are direct sowing (dry direct seeding and wet direct seeding) and transplanting (Kuotsuo *et al.*, 2014; Chatterjee *et al.* 2016) [5, 6]. Presently in, India, direct seeded rice is gaining momentum due to labour shortage during peak season of transplanting and availability of water for short periods (Prakash *et al*., 2014; Singh *et al*., 2017) [7, 8]. In recent years there is a serious concern about the availability of water for rice production due to sharp decrease in water table (Hugar *et al.*, 2009) [9]. Thus there is a shift from transplanting to direct seeded rice (DSR) in many countries including India. Dry seeding reduces the overall water demand of rice by reducing water needed for land preparation, losses due to evaporation, leaching, percolation etc. (Bouman and Tuong, 2001) [10]. In the face of increasing population and growing demand for food the upgrading of rainfed areas through DSR technology can help in soil and water conservation and deal with risks arising from climate change. With this ideas in mind, this investigation was planned to find out water productivity and nutrient uptake of direct seeded early *ahu* rice under medium land situation.

## Material and Methods
The experiment was conducted during the autumn season at Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat-13. The site selected for conducting the experiment was under medium low land situation. The soil of the experimental plot was silt loam in texture, acidic in reaction having pH 5.2, 0.72% organic carbon, low in available N (181.0 kg/ha) and medium in available $P_2O_5$ (24.5 kg/ha) and $K_2O$ (273.5 kg/ha). It contained 27.6% soil moisture at Field Capacity and 9.6% at Permanent Wilting Point with bulk density of 1.34 g/cc. The experiment was laid out in split plot design with 3 replications and

13 treatments. The main plot treatment included $I_1$ : Irrigation at 80% available water till onset of pre-monsoon rain, $I_2$ : Irrigation at 70% available water till onset of pre-monsoon rain, $I_3$ : Irrigation at 60% available water till onset of pre-monsoon rain and $I_4$ : rainfed. The subplot treatment included nutrient management *viz*. $N_1$: Full P as basal + ½ N and ½ K at 20 DAS + ½ N and ½ K at 40 DAS, $N_2$: Full P as basal and $^1/_3$ N and $^1/_3$ K as basal + $^1/_3$ N and $^1/_3$ K at 20 DAS + 1/3 N and $^1/_3$ K at 40 DAS and $N_3$: Full P as basal and ½ N and ½ K as basal + ¼ N and ¼ K at 20 DAS + ¼ N and ¼ K at 40 DAS. A control treatment *i.e.* transplanted early *ahu* rice with recommended water and fertilizer management practices was included. The rice variety "Inglongkiri" was sown on 18th February, 2017 with seed rate 75 kg/ha. On the same day, seeds were soaked to sow in nursery bed for transplanting in control plot with seed rate 45 kg/ha and transplanted on 17th March, 2017. Recommended dose of fertilizer @ 40-20-20 as $N-P_2O_5-K_2O$ kg/ha was applied in the form of urea, SSP and MOP. Fertilizers were applied as per treatment. In control plot, full $P_2O_5$ and $K_2O$ and half N were applied as basal. One fourth N was applied at maximum tillering and one fourth N was applied at panicle initiation stage. In direct sowing plots, sowing was done manually by line sowing. Seedlings were transplanted on 17th March, 2017 by maintaining a spacing of 20 cm × 15 cm in the control plot. Two weedings were done at 3 weeks and 6 weeks after sowing by manual hoeing to reduce the ill effect of weeds which makes the environment unfavorable for growth of rice. In transplanted crop, Japanese Paddy Weeder was operated after top dressing of urea to incorporate the fertilizer as well as to control the weeds. Irrigation was applied as per treatment. In each plot, 5 cm irrigation water was applied when water level depleted to a certain level as per treatment. During the entire period of investigation, 768.0 mm rainfall was received. The grain and straw yields were measured separately in kg per plot and converted to kg per ha (at 14% moisture content in grain). 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 (%). Expected nutrient balance, Actual gain/loss of nutrients and Apparent gain/ loss of nutrients were calculated as per Singh *et al*. (2017) [11]. 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) [12].

## Results and Discussion

### Water use and water productivity

The data on water use and water productivity are presented in Table 1. Direct seeded rice with irrigation at 80% available water recorded 34.2% lower water use and 62.5% saving of irrigation water use than transplanted rice. A 19% irrigation water savings and 11% increase in input water productivity (0.20 g grains/litre) was observed by Bhusan *et al*. (2007) [13] with direct seeded rice, when irrigation was scheduled at 33 kpa. Castaneda *et al.* (2003) [14] reported a saving of 73% water in land preparation in aerobic rice system. Bouman *et al.* (2005) [15] studied that on average, aerobic fields used 190 mm less water in land preparation and had 250-300 mm less seepage and percolation, 80 mm less evaporation and 25 mm less transpiration than flooded fields when irrigation was applied need based. The large irrigation water savings in direct seeded rice applied with differential irrigation schedules compared to continuous flooding conditions was consistent with the findings of many other studies reviewed by Singh *et al.* (2002) [16] and Humphreys *et al.* (2010) [17].

**Table 1:** Effect of irrigation schedule and nutrient management on nutrient content and uptake

| Treatment | Nutrient content (%) | | | | | | Nutrient uptake (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | P | | K | | N | P | K |
| | Grain | Stover | Grain | Stover | Grain | Stover | | | |
| **Irrigation Schedule (I)** | | | | | | | | | |
| $I_1$ | 1.55 | 0.73 | 0.34 | 0.17 | 0.73 | 1.38 | 105.5 | 24.3 | 124.2 |
| $I_2$ | 1.59 | 0.70 | 0.35 | 0.17 | 0.72 | 1.35 | 91.7 | 20.1 | 105.4 |
| $I_3$ | 1.50 | 0.75 | 0.33 | 0.17 | 0.75 | 1.40 | 84.9 | 19.3 | 102.3 |
| $I_4$ | 1.60 | 0.70 | 0.33 | 0.17 | 0.70 | 1.36 | 80.1 | 18.3 | 95.2 |
| SEm ± | 0.6 | 0.3 | 0.02 | 0.02 | 0.03 | 0.06 | 3.3 | 1.2 | 3.9 |
| $CD_{0.05}$ | NS | NS | NS | NS | NS | NS | 10.6 | 3.9 | 12.8 |
| **Nutrient management (N)** | | | | | | | | | |
| $N_1$ | 1.61 | 0.71 | 0.35 | 0.17 | 0.76 | 1.36 | 98.2 | 22.3 | 115.6 |
| $N_2$ | 1.57 | 0.72 | 0.35 | 0.17 | 0.72 | 1.33 | 90.3 | 20.4 | 106.0 |
| $N_3$ | 1.59 | 0.70 | 0.33 | 0.17 | 0.72 | 1.32 | 83.1 | 18.8 | 98.7 |
| SEm ± | 0.05 | 0.2 | 0.03 | 0.02 | 0.02 | 0.05 | 2.8 | 1.0 | 3.3 |
| $CD_{0.05}$ | NS | NS | NS | NS | NS | NS | 8.2 | 2.9 | 9.8 |
| Interaction (I×N) | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Control vs treatment** | | | | | | | | | |
| Treatment | 1.60 | 0.70 | 0.35 | 0.18 | 0.72 | 1.34 | 90.5 | 20.5 | 106.8 |
| Control | 1.61 | 0.71 | 0.35 | 0.18 | 0.70 | 1.30 | 92.2 | 22.2 | 110.2 |
| SEm ± | 0.05 | 0.03 | 0.03 | 0.02 | 0.04 | 0.06 | 5.888 | 0.92 | 0.9 |
| $CD_{0.05}$ | NS | NS | NS | NS | NS | NS | NS | NS | NS |

The consumptive use is said to be more dependent on the evaporative demand of the atmosphere and vegetative growth of crop species. In the present study, amongst the direct seeded rice, the highest consumptive use and water use efficiency (WUE) was observed under irrigation at 80% available water ($I_1$). The evapotranspiration of the crop increased under irrigation at 80% available water ($I_1$). Higher consumptive use of water with this treatment might be due to the fact that under more frequent wetting cycle, crop evapotranspiration was higher due to the availability of more water as compared to the crop irrigated at wider interval. These are in general agreement with those of Sarma and Das (2013) [18], Sarma and Das (2017) [19] and Deka *et al.* (2018) [20]. Irrigation at 80% available water also recorded the highest water productivity. This may be due to their favourable effect on yield attributing characters and yield. Transplanted crop recorded the lower water productivity than direct seeded rice. This might be due to consumption and use of more water as compared to production of grain. Sarma and Das (2013) [18] also reported decrease in water use efficiency with increase in water use.

Under nutrient management treatments, full P as basal + ½ N and ½ K at 20 DAS + ½ N and ½ K at 40 DAS ($N_1$) recorded the highest water use, consumptive use and water productivity than full P, $^1/_3$ N and $^1/_3$ K as basal + $^1/_3$ N and $^1/_3$ K at 20 DAS + $^1/_3$ N and $^1/_3$ K at 40 DAS ($N_2$) and full P, ½ N and ½ K as basal + ¼ N and ¼ K at 20 DAS + ¼ N and ¼ K at 40 DAS ($N_3$). This may be due to their favourable effect on yield attributing characters and yield. The role of nitrogen include enhancing protein content, membrane stability, plant biomass and membrane polarization which ultimately results in enhanced water productivity (Waraich *et al*., 2010) [21]. K affects water productivity through its functions in stomatal regulation, osmoregulation, energy status, charge balance, protein synthesis and homeostasis (Beringer and Trolldenier, 1978; Marschener, 1995) [22, 23]. It also maintains turgor pressure (Mengel and Arneke, 1982) [24] and regulate transpirational water loss (Beringer and Trolldenier, 1978) [22]. It can be better understood that increased water productivity in the best treatments are attributed to the synchrony between crop demand and nutrient supply at right time accompanied by ample water supply. Collateral findings regarding this fact have been reported by Sarkar *et al.* (2016) [25].

**Nutrient content and uptake**

In the present experiment, no significant differences were observed among the nitrogen, phosphorus and potassium content of the crop (Table 2). On the other hand, the nitrogen, phosphorus and potassium uptake by the crop differed significantly where the highest uptake was recorded by irrigation at 80% available water ($I_1$). This might be due to the fact that under adequate soil moisture, there is more solubilization of nutrients particularly phosphorous and thereby increases uptake by increasing availability to plants (Sandhu and Mahal, 2014) [26]. The total nutrient uptake did not differ significantly in both direct seeding and transplanting. The direct seeded rice might have overcome the effects of non puddling by inducing a robust root system. The capacity of the plant to absorb water and nutrients is closely related to the total length of the root system. Direct seeded (aerobic) rice seedlings have higher starch and protein content and thus have higher rooting capacity than lowland-grown (anaerobic) seedlings (Jungk and Barber, 1974; Huang, 2017) [27, 28].

**Table 2:** Effect of irrigation schedule and nutrient management on consumptive use, water use and water productivity

| Treatment | Consumptive use (cm) | Irrigation water used (cm) | Total water used (cm) | Water productivity (kg/m$^3$) |
|---|---|---|---|---|
| **Irrigation Schedule (I)** | | | | |
| $I_1$ | 40.6 | 15.0 | 77.7 | 0.510 |
| $I_2$ | 38.9 | 10.0 | 72.9 | 0.475 |
| $I_3$ | 37.5 | 5.0 | 68.3 | 0.462 |
| $I_4$ | 36.9 | 0 | 63.0 | 0.461 |
| **Nutrient management (N)** | | | | |
| $N_1$ | 40.0 | 7.5 | 71.2 | 0.522 |
| $N_2$ | 38.2 | 7.5 | 70.4 | 0.477 |
| $N_3$ | 37.2 | 7.5 | 69.9 | 0.432 |
| **Treatment vs control** | | | | |
| Treatment | 38.5 | 7.5 | 70.5 | 0.477 |
| Control | 46.3 | 40.0 | 118.1 | 0.314 |

Under nutrient management treatments, full P as basal + ½ N and ½ K at 20 DAS + ½ N and ½ K at 40 DAS ($N_1$) recorded the highest uptake of N, P and K than full P, $^1/_3$ N and $^1/_3$ K as basal + $^1/_3$ N and $^1/_3$ K at 20 DAS + $^1/_3$ N and $^1/_3$ K at 40 DAS ($N_2$) and full P, ½ N and ½ K as basal + ¼ N and ¼ K at 20 DAS + ¼ N and ¼ K at 40 DAS ($N_3$). As reported by Somaweera *et al*. (2016), rice plants continued to take up N and K until maturity while P uptake continued until the mid-grain filling stage. Thus, two splits with 50% N and K at 20 and 40 DAS were more beneficial for the crop than three splits with 33.3% N and K at 0, 20 and 40 DAS ($N_2$) and 50% N and K at 0 DAS + 25% N and K each at 20 and 40 DAS ($N_2$). The more uptake might be due to the amount applied at the most nutrient requiring phase of the crop life cycle and maintenance of conducive moisture condition for crop need (Meisner *et al*., 2002) [29]. The congenial conditions favoured luxuriant growth of the plants which ultimately might have resulted in more photosynthetic rate and nutrient uptake for dry matter production. Collateral findings have been reported by Bhanuvally (2017) [30].

**Nutrient Balance**

The data pertaining to available N, $P_2O_5$ and $K_2O$ balance in soil after harvest of rice as influenced by the irrigation treatments and nutrient management practices is presented in Table 3. Expected N balance was highest in rainfed direct seeded rice ($I_4$) [140.9 kg/ha] and lowest in application of irrigation at 80% available water till onset of pre-monsoon rain ($I_1$) [115.5 kg/ha]. All the irrigation treatments recorded the actual loss and apparent gain of N from the soil. Application of irrigation at 80% available water till onset of pre-monsoon rain ($I_1$) recorded the highest actual loss (10.5 kg/ha) apparent gain from soil (55.0 kg/ha). On the other hand, rainfed crop ($I_4$) recorded the lowest actual loss (4.6 kg/ha) and apparent gain from soil (35.5 kg/ha).

**Table 3:** Effect of irrigation schedule and nutrient management on nutrient balance

| Treatments | N | | | P | | | K | | |
|---|---|---|---|---|---|---|---|---|---|
| | Expected nutrient balance (kg/ha) | Actual gain/loss of nutrients (kg/ha) | Apparent gain / loss from soil or immobilization of nutrients in soil (kg/ha) | Expected nutrient balance (kg/ha) | Actual gain/loss of nutrients (kg/ha) | Apparent gain / loss from soil or immobilization of nutrients in soil (kg/ha) | Expected nutrient balance (kg/ha) | Actual gain/loss of nutrients (kg/ha) | Apparent gain / loss from soil or immobilization of nutrients in soil (kg/ha) |
| **Irrigation schedule** | | | | | | | | | |
| $I_1$ | 115.5 | -10.5 | 55.0 | 6.4 | -0.9 | 20.3 | 123.7 | -20.2 | 84.0 |
| $I_2$ | 129.3 | -8.7 | 43.0 | 10.6 | -0.8 | 18.6 | 142.5 | -19.4 | 66.0 |
| $I_3$ | 136.1 | -6.8 | 38.1 | 11.4 | -0.6 | 16.9 | 145.6 | -13.2 | 69.1 |
| $I_4$ | 140.9 | -4.6 | 35.5 | 12.4 | -0.1 | 15.2 | 152.7 | -8.3 | 67.0 |
| **Nutrient management** | | | | | | | | | |
| $N_1$ | 122.8 | -8.2 | 50.0 | 8.4 | -0.8 | 18.1 | 132.3 | -23.8 | 71.9 |
| $N_2$ | 130.7 | -7.8 | 42.5 | 10.3 | -0.7 | 17.8 | 141.9 | -14.8 | 71.3 |
| $N_3$ | 137.9 | -7.0 | 36.1 | 11.9 | -0.4 | 17.3 | 149.2 | -7.3 | 71.5 |
| **Control vs Treatment** | | | | | | | | | |
| Treatment | 130.5 | -4.5 | 46.0 | 10.2 | -0.6 | 14.6 | 141.1 | -15.5 | 71.6 |
| Control | 128.8 | -7.6 | 44.6 | 8.5 | -0.8 | 17.5 | 137.7 | -20.2 | 70.0 |

[Expected nutrient balance = Initial available nutrient + Nutrient added - Nutrient uptake; Actual gain/loss of nutrients = Final value of available nutrient (after the harvest of crop) - Initial value of available nutrients; Apparent gain/ loss of nutrients from soil or immobilization of nutrients in soil = Final value of available nutrient (after the harvest of crop) - Expected nutrient balance]

Among the nutrient management treatments, expected N balance was highest in full P and ½ N and ½ K as basal + ¼ N and ¼ K at 20 DAS +¼ N and ¼ K at 40 DAS ($N_3$) [137.9 kg/ha] and lowest in application of full P as basal + ½ N and ½ K at 20 DAS + ½ N and ½ K at 40 DAS ($N_1$) [122.8 kg/ha]. All the nutrient management treatments recorded the actual loss and apparent gain of N from the soil. Application of full P as basal + ½ N and ½ K at 20 DAS + ½ N and ½ K at 40 DAS ($N_1$) recorded the highest actual loss (8.2 kg/ha) and apparent gain from soil (50.0 kg/ha) followed by full P as basal and $^1/_3$ N and $^1/_3$ K as basal + $^1/_3$ N and $^1/_3$ K at 20 DAS + $^1/_3$ N and $^1/_3$ K at 40 DAS ($N_2$) [7.8 and 42.5 kg/ha]. The lowest actual gain (7.0 kg/ha) and apparent gain (36.1 kg/ha) of N from the soil were recorded in full P and ½ N and ½ K as basal + ¼ N and ¼ K at 20 DAS + ¼ N and ¼ K at 40 DAS ($N_3$).

Expected N balance in direct seeded rice (130.5 kg/ha) is higher than transplanted rice (control) [128.8 kg/ha]. Transplanted crop recorded the higher actual loss (7.6 kg/ha) and lower apparent gain (44.6 kg/ha) from soil than direct seeded crop (4.5 and 46.0 kg/ha).

## Conclusion

Under medium land situation, direct seeding, instead of transplanting, increases the nutrient uptake and water productivity of rice. Under direct seeded condition, crop should be irrigated at 80% available water till onset of pre monsoon rain. Nitrogenous and potassic fertilizer should be applied as top dressing in two splits for higher nutrient balance and water productivity.

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