Effects of Irrigation Frequency and Nitrogen Fertilizer Application on Yield and Water Use Efficiency of Lowland Rice (*Oryza sativa* L.) in Northeastern Nigeria

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Abstract: Irrigation water and nitrogen fertilizer are the two most important factors limiting the yield of lowland rice plant in most rice producing soils of northeastern Nigeria. In view of this an experiment was conducted at the Lake Geriyo irrigation scheme farms in Yola Adamawa State, Nigeria to study the effects of irrigation intervals and nitrogen fertilizer rates on lowland rice (Faro 44). The experiment was laid out in split plot design, where three irrigation frequencies (4, 8 and 12 days irrigation intervals) were used as main plot factors while nitrogen fertilizer rates (0, 50, 100 and 150kg N ha⁻¹) as sub plot factors. Results obtained indicated that irrigation interval and nitrogen levels influenced grain yield, straw yield and harvest index of rice significantly (P ≤ 0.05) which showed increasing trend with increase in nitrogen levels at 4 days irrigation interval. Maximum grain yield (5725.67 kg ha⁻¹), straw yield (6465.26 kg ha⁻¹) and harvest index (47.15%) were achieved with 4 days irrigation interval and 150 kg N ha⁻¹. Irrigation water use efficiency (IWUE) was higher at 8 days irrigation interval with 100 and 150kg N ha⁻¹ thus saving about 48% water compared to 4 days irrigation interval which saved only 13%. It is concluded that increasing the irrigation interval from 4 to 8 days on the clay loam soils of northeastern Nigeria can result in substantial irrigation water savings so that larger areas of rice would be cultivated. Therefore 8 days irrigation interval and 100kg N ha⁻¹ is recommended for rice farmers in the study area for improve water use efficiency.

Keywords: irrigation, nitrogen, rice, yield and water use efficiency

I. INTRODUCTION

One of the major challenges for food security in the world is ever increasing population growth requiring a significant increase in food supply. This is further threatened by water scarcity which is a major threat for sustainable rice production worldwide. It is of utmost importance to explore alternate ways of rice production by using less water for food security [1]. Water is one of the major factors in rice production with increasing scarcity of water; the costs of its use and resource development. Therefore, farmers and researchers alike are looking for ways to decrease water use in rice production, increase its use efficiency and increase yield of paddy rice [2]. Traditional rice cultivation uses flood water management which requires various inputs that are costly and time consuming. In addition, it requires large quantities of water. Water management is not just about how water is delivered but also when, how often, and how much water is use to obtained maximum yield [3]. To increased water productivity under increasing scarcity of water resources, intermittent irrigation has been developed as a water-saving technique and adopted in many countries such as China, Bangladesh, and India [4]. Irrigation interval is the use of alternate irrigations during rice growing seasons and is one of the most important ways to saving irrigation water without reducing rice areas [5] Application of intermittent irrigation can maintain or even increase grain yield because of the enhancement in root growth and grain-filling rate [6]. The great challenge for agriculture is to produce more rice with less water if food security is to be maintained, thus, irrigation water use efficiency should play a greater role in meeting future rice demands [7]. The only solution for worldwide water shortage and utilization problem is to make efficient use of agricultural water for improve crop productivity [8].
Irrigation interval method is the most common practice among rice farmers in rural communities of Nigeria. Determination of suitable irrigation frequency that will improve the water use efficiency and save cost becomes very important. Little information is available on improving water use efficiency of rice in the savanna ecological zone of Nigeria.

Another area of concern is the proper nitrogen fertilizer management which is vital in improve rice crop growth and grain yields [9]. This is more so important considering the low levels of nitrogen in the soils of northern guinea savanna zone of Nigeria [10, 11] and is also most limiting nutrient for rice production worldwide [12]. Selection of the appropriate level of N fertilizer is a major concern for achieving economic benefit of the crop by decreasing the quantity and increasing its efficiency while maintaining a sound environment [13]. Because of the difficulty in predicting N fertilizer requirements, farmers often apply higher levels than those needed to maintain yield [14] therefore to quantify appropriate N fertilizer rates for enhancing crop productivity becomes very important also. The study was undertaken to determine the effect of different irrigation frequencies and nitrogen rates on the yield and irrigation water use efficiency of lowland rice in a northern guinea savanna ecological zone of Nigeria.

II. MATERIALS AND METHODS

The study area lies within the Northern Guinea Savannah zone of Nigeria, (9° 23’ N, 12° 46’ E and 152m above sea level). Experiments were carried out at the Lake Geriyo irrigation scheme farms, Yola, the Capital of Adamawa State, Nigeria during the 2011/2012 and 2012/2013 dry seasons cropping period. The major sources of the irrigation water for the area are Benue River, Lake Geriyo and tube wells. Rice is the major crop grown in the area followed by other vegetables [15]. The geology of the area is underlain by the Bima sandstone and recent river alluvium. [16]. The area is characterized by an average annual rainfall of between 900–1000mm, unimodal in distribution, with much of the rain falling between months of May and October; the mean length of the dry season is about 160 – 200 days (November to April) during which no precipitation occurs. Mean daily air temperatures (minimum and maximum) range between 18°C and 40°C. The wind speed ranges from 88km/day in October to 284km/day in March. The humidity may be as low as 10 to 20% during the dry season and about 80% in August [17]. The vegetation of the area is that of the Northern guinea savanna dominated by small to medium trees and shrubs [18, 19] while, the soils of the area are classified as Typic Haplustalf [20].

Soils of the area were analyzed for different physico-chemical properties following the methods described in Ryan et al. [21].

The experiment consisted of three irrigation intervals and four nitrogen rates as:

$I_1 = 4$ days irrigation interval (commonly practiced by rice farmers at the study area, served as the control),
$I_2 = 8$ days irrigation interval, $I_3 = 12$ days irrigation interval and

Nitrogen fertilizer rates are $N_1 = 0$ kg N ha$^{-1}$, $N_2 = 50$ kg N ha$^{-1}$, $N_3 = 100$ kg N ha$^{-1}$ and $N_4 = 150$ kg N ha$^{-1}$.

The main plots measured 12 x 12m while, sub plots were 4x3m in area. The experiment was laid out in a Randomized Complete Block Design with split plot arrangement while each treatment was replicated three times. The field was puddled and leveled before transplanting in order to allow uniform flow of water during irrigation. Surface irrigation method was used in conveying water into each basin. The canals were lined with polyethylene sheet to prevent seepage and allow free flow of water into targeted basins. This methodology was adopted because of its ease of application by mostly poor, illiterate farmers in the study area.
The timed volume-container head method (bucket system) was employed during each irrigation scenario in calculating the amounts of water applied into required depth as described by [22] as

\[ D = \frac{V}{T} \]

Where \( D \) is the discharge rate (milliliters/seconds), \( V \) is the volume of the container (milliliter), \( T \) is the time taken to fill the container (seconds).

Rice variety FARO 44 seedlings were transplanted to the field at 30 days after sowing at the rate of two seedlings per hill with a spacing of 20cm x 20cm. Phosphorus and Potassium fertilizers were applied to all plots one week before transplanting at the rate of 60kg P\(_2\)O\(_5\) and 60kg K\(_2\)O per hectare using Single Super Phosphate Fertilizer (SSP) and Muriate of Potash respectively as recommended by [23] under low soil fertility class. The Nitrogen fertilizer was applied by broadcasting to each plot according to the nitrogen treatments, using Urea fertilizer in three equal doses, at transplanting, 3 week after transplanting and six weeks after transplanting. Weeding was carried out regularly through hand pulling of weeds. At maturity an area 8m\(^2\) in the center of each plot was harvested for grain and straw weight analysis while harvest index (HI) was determined using the expression in [24]:

\[ HI = \frac{GY}{BY} \times 100 \]

Where HI is Harvest Index (%), GY is grain yield (kg ha\(^{-1}\)) and BY is biological yield (straw yield + grain yield in kg ha\(^{-1}\)).

Irrigation water use efficiency (IWUE) was calculated using the expression described by Kirda [25]:

\[ IWUE \ (kg \ m^{-3}) = \frac{Grain \ yield \ (kg \ ha^{-1})}{Irrigation \ water \ applied \ (m^3 ha^{-1})} \]

Data collected from the experiments were subjected to ANOVA and means were separated by tukey’s HSD using the R statistical package [26].

III. RESULTS AND DISCUSSION

Results showed (Table 1) that the soil textural class was clay loam with a bulk density of 1.53g cm\(^{-3}\) and basic infiltration rate of 17.14mm hr\(^{-1}\). The pH of the soils is moderately acidic both in water (5.63) and 0.01M CaCl\(_2\) (6.10), EC (1.82ds m\(^{-1}\)) was rated low and organic carbon content (0.64g kg\(^{-1}\)) very low. Total nitrogen (0.08g kg\(^{-1}\)), available phosphorus (2.04mg kg\(^{-1}\)), Ca\(^{2+}\) (2.25cmol kg\(^{-1}\)), Mg\(^{2+}\) (0.33 cmol kg\(^{-1}\)), Na\(^{+}\) (0.30 cmol kg\(^{-1}\)) and K\(^{+}\) (0.44) ECEC was 3.81 cmol kg\(^{-1}\) were also rated low Esu [27].

| TABLE 1: Initial Physico-chemical Properties of the Soils of the Experimental Site |
|---------------------------------|----------------|
| Properties                      | Value          |
| Sand (g kg\(^{-1}\))            | 393.70         |
| Silt (g kg\(^{-1}\))            | 241.30         |
| Clay (g kg\(^{-1}\))            | 365.00         |
| Textural class                  | Clay loam      |
| Bulk density (g cm\(^{-3}\))    | 1.53           |
| Basic Infiltration rate (mm hr\(^{-1}\)) | 17.14       |
| pH (Water)                     | 6.10           |
| pH (0.01M CaCl\(_2\))          | 5.63           |
| Electric Conductivity (dS m\(^{-1}\)) | 1.82       |
| Organic Carbon (g kg\(^{-1}\))  | 6.40           |
| Organic Matter (g kg\(^{-1}\))  | 11.01          |
| Total Nitrogen (g kg\(^{-1}\))  | 0.80           |
| Available Phosphorus (mg kg\(^{-1}\)) | 2.04       |
| Calcium (Ca\(^{2+}\))          | 2.25           |
| Magnesium (Mg\(^{2+}\))        | 0.33           |
| Sodium (Na\(^{+}\))            | 0.14           |
| Potassium (K\(^{+}\))          | 0.44           |
| Effective Cation Exchange Capacity (ECEC) | 3.86       |
The results on grain yield, straw yield, harvest index, water used and irrigation water use efficiency (IWUE) in both 2011/2012 and 2012/2013 dry season cropping periods indicated significant ($P<0.05$) effects of the treatments on observed parameters (Tables 2 and 3). Highest grain yield (4283.64 and 5005.09 kg ha$^{-1}$) was recorded at 4 days irrigation interval ($I_1$) in both seasons but was statistically at par with 8 days irrigation interval in 2011/2012 season as similarly reported by [28]. However minimum grain yield (1191.26 and 1364.97 kg ha$^{-1}$) was found in 12 days irrigation interval regime ($I_3$). This indicated greater yield reduction with the decrease in irrigation frequency. Closely related results were reported in [29] that irrigation every 4 days surpassed other irrigation intervals (9 and 11 days) on rice grain yield, straw yield and harvest index. The effect of nitrogen fertilizer rates on grain yield showed that maximum grain yield was obtained with application of 150 kg N ha$^{-1}$ and the minimum was in control treatments (0 kg N ha$^{-1}$). This corroborates the works of Shirazi et al. [30] The grain yield was maximum due to application of 120 kg N ha$^{-1}$ and statistically similar to that of 100 kg N ha$^{-1}$. It also in agreement with those reported those reported by [31, 32, 33] that higher grain yield were obtained at high nitrogen rates than in control.

### Table 2: Mean Main Effects of Irrigation Regimes and Nitrogen Rates on Grain and Straw Yield, Harvest Index (HI), Water Used and Irrigation Water Use Efficiency (IWUE) in 2011/2012

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain Yield (kg ha$^{-1}$)</th>
<th>Straw Yield (kg ha$^{-1}$)</th>
<th>Harvest Index (%)</th>
<th>Total water used (m$^3$ ha$^{-1}$)</th>
<th>IWUE (kg m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation regimes</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$I_1$</td>
<td>4283.64</td>
<td>6002.52</td>
<td>42.14</td>
<td>15690.00</td>
<td>0.27</td>
</tr>
<tr>
<td>$I_2$</td>
<td>3557.08</td>
<td>4907.17</td>
<td>42.02</td>
<td>8158.80</td>
<td>0.44</td>
</tr>
<tr>
<td>$I_3$</td>
<td>1191.26</td>
<td>2818.11</td>
<td>29.71</td>
<td>5020.80</td>
<td>0.24</td>
</tr>
<tr>
<td>HSD($P&lt;0.05$)</td>
<td>840.52</td>
<td>697.28</td>
<td>3.97</td>
<td>346.35</td>
<td>0.14</td>
</tr>
<tr>
<td>Nitrogen rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N_0$</td>
<td>1990.05</td>
<td>3652.66</td>
<td>33.26</td>
<td>10649.67</td>
<td>0.19</td>
</tr>
<tr>
<td>$N_1$</td>
<td>2775.13</td>
<td>4587.64</td>
<td>37.69</td>
<td>10649.67</td>
<td>0.26</td>
</tr>
<tr>
<td>$N_2$</td>
<td>3296.31</td>
<td>4763.16</td>
<td>39.40</td>
<td>10649.67</td>
<td>0.31</td>
</tr>
<tr>
<td>$N_3$</td>
<td>3454.17</td>
<td>4966.16</td>
<td>41.04</td>
<td>10649.67</td>
<td>0.32</td>
</tr>
<tr>
<td>HSD($P&lt;0.05$)</td>
<td>1066.62</td>
<td>1047.62</td>
<td>4.89</td>
<td>NS</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Where: $I_1$ = 4 days irrigation interval, $I_2$ = 8 days irrigation interval, $I_3$ = 12 days irrigation interval, $N_0$ = 0 kg N ha$^{-1}$, $N_1$ = 50 kg N ha$^{-1}$, $N_2$ = 100 kg N ha$^{-1}$ and $N_3$ = 150 kg N ha$^{-1}$, NS = not significant, HSD = Tukey Honesty Significant Difference, * = significant at 5% probability

The interaction effect of irrigation and nitrogen levels on grain yield was significant ($p < 0.05$) in both years. The treatment $I_1N_3$ produced the maximum yield in both years, while the minimum was found in $I_3N_0$. This result was in agreement with those reported by [29] who recorded higher rice grain yields with the interaction of irrigation at 4 days interval and high level of N fertilizer. The maximum straw yield (6002.52 and 6295.53 kg ha$^{-1}$) was also recorded with 4 days irrigation interval ($I_1$) while the minimum straw yield (2818.11 and 2857.56 kg ha$^{-1}$) was found under 12 days irrigation interval ($I_3$). Straw yield followed the similar pattern as in grain yield. This showed a reduction in whole plant dry weight with the increase in irrigation interval which could be associated to reduction in the rates of cell division and cell extension in the leaves that leads to less photosynthesis hence retarding overall plant growth as the resources required for growth processes become limited in supply as opined by [34]. Rice responses to water availability differ as revealed that when irrigation is delayed total biomass decreased [35]. The nitrogen fertilizer rates showed significant ($p < 0.05$) increased in straw yield with increasing N fertilizer level where maximum yield (4766.16 and 4871.08 kg ha$^{-1}$) was reached with 150 kg N ha$^{-1}$ ($N_3$) and minimum with $N_0$ treatments in both cropping seasons respectively.
The results are supported by the works of [36] who found that increasing N application (120-160 kg ha⁻¹) increased straw yield in rice. Nitrogen is known to promote tillering, improved length and width of leaves which in turn increases the plant height and dry matter which are responsible for increase in straw yield. The interaction of irrigation regime and nitrogen level on straw weight was also significant. I₁N₂, I₁N₃ and I₂N₃ produced higher but, statistically at par straw weight while the minimum was recorded with I₃N₀ in both seasons. Similar results were noted by Ashouri [34] where a combination of 5 and 8 days irrigation intervals with 150 kg N ha⁻¹ rate produced higher grain and straw weight that are statistically at par.

### TABLE 3: Mean Main Effects of Irrigation Regimes and Nitrogen Rates on Grain and Straw Yield, Harvest Index (HI), Water Used and Irrigation Water Use Efficiency (IWUE) in 2012/2013

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain Yield (kg ha⁻¹)</th>
<th>Straw Yield (kg ha⁻¹)</th>
<th>Harvest Index (%)</th>
<th>Total water used (m³ ha⁻¹)</th>
<th>IWUE (kg m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Irrigation regimes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I₁</td>
<td>5005.09</td>
<td>6209.98</td>
<td>44.63</td>
<td>16110.00</td>
<td>0.31</td>
</tr>
<tr>
<td>I₂</td>
<td>3798.86</td>
<td>5112.47</td>
<td>42.63</td>
<td>8377.20</td>
<td>0.45</td>
</tr>
<tr>
<td>I₃</td>
<td>1364.97</td>
<td>2912.07</td>
<td>31.91</td>
<td>5955.20</td>
<td>0.23</td>
</tr>
<tr>
<td>HSD(P&lt;0.05)</td>
<td>857.35</td>
<td>651.61</td>
<td>3.13</td>
<td>342.16</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Nitrogen rates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N₀</td>
<td>2151.00</td>
<td>3720.04</td>
<td>34.40</td>
<td>11277.00</td>
<td>0.19</td>
</tr>
<tr>
<td>N₁</td>
<td>3088.06</td>
<td>4575.05</td>
<td>40.30</td>
<td>11277.00</td>
<td>0.27</td>
</tr>
<tr>
<td>N₂</td>
<td>3586.60</td>
<td>5022.42</td>
<td>41.66</td>
<td>11277.00</td>
<td>0.32</td>
</tr>
<tr>
<td>N₃</td>
<td>3994.43</td>
<td>5168.72</td>
<td>43.59</td>
<td>11277.00</td>
<td>0.35</td>
</tr>
<tr>
<td>HSD(P&lt;0.05)</td>
<td>1008.48</td>
<td>1005.44</td>
<td>3.99</td>
<td>NS</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
<td></td>
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</tr>
</tbody>
</table>

Where: I₁=4 days irrigation interval, I₂=8 days irrigation interval, I₃=12 days irrigation interval, N₀=0 kg N ha⁻¹, N₁=50kg N ha⁻¹, N₂=100kg N ha⁻¹ and N₃=150kg N ha⁻¹. NS= not significant, HSD= Tukey Honesty Significant Difference, * = significant at 5% probability

Harvest index was also maximum (41.64 and 44.29%) with I₁ in the two seasons respectively. The result was statistically at par with 8 days irrigation interval (I₂). While the minimum (29.71 and 32.23%) for the 2011/2012 and 2012/2013 season respectively were recorded in I₃ treatments. Lack of significant difference between 6 and 9 days’ interval irrigations on harvest index, but higher from 6 days irrigation interval was recorded by [37]. The effect of nitrogen levels on harvest index was remarkably significant in the two seasons. The harvest index was higher (45.33 and 43.54%) with 150kg N ha⁻¹ compared to 0 and 50 kg N ha⁻¹ except for 100 kg N ha⁻¹ in 2011/2012 season. The lowest harvest index was produced with 0kg N ha⁻¹ in both seasons. The results are in conformity with those of [38] who reported highest harvest index with 150kg N ha⁻¹ as compared to 100, 50 and the minimum with 0kg N ha⁻¹. The result was in contrast with the findings of [39] who reported no significant effect of nitrogen rate on rice grain harvest index.

The total water used and irrigation water use efficiency were significantly influenced by the irrigation interval in both seasons (Table 2 and 3). The 4 days irrigation interval treatment consumes large quantities of water (mean of 15900 m³ ha⁻¹) during the rice growth cycle, while the minimum (5487.60 m³ ha⁻¹) quantity of water used was obtained with 12 days irrigation interval (Table 4). FAO [40] reported that high water consumption of approximately 20,000 m³ ha⁻¹ results in low water productivity. Ragab [41] reported 16, 500 m³ ha⁻¹ as an average total water requirement for lowland rice production under different conditions for a yield of 4.5 tons/ha. The percent water saving as regard the irrigation intervals from the commonly practiced irrigation interval by farmers at study area (4 days interval) were, I₁ = 48% and I₃ = 68% which resulted in grain yield reduction by 17% and 72%, for 2011/2012 season and 21% and 73% in 2012/2013 season respectively. It was reported that amount of water saved due to increasing irrigation intervals from 3 days to 6, 9 and 12 days to be 16.7, 27.4 and 36.7% [41].
Irrigation water use efficiency (IWUE) of rice plants was significantly influenced by the irrigation intervals and nitrogen rates in both seasons (Table 2 and 3). 8 days irrigation interval had maximum (0.45) value of IWUE for the two seasons, while 12 days irrigation interval treatments had minimum (0.24) values in both years (Table 4). This showed that irrigation at 8 days frequency satisfied most of the moisture requirement of the crop at all growth stages. The result is in agreement with reported observations of [42] where 8 days irrigation interval recorded higher WUE than 4 days interval. Also [43] reported that prolonging the period of irrigation up to 9 days frequency adversely affected paddy yield in sandy loam soil, but was not so in clay loam soil. The IWUE was observed to increase significantly with N application rates in both seasons. The N₁ treatment had the highest IWUE value among the N treatments in both years. Similar results were reported by [11, 33, 44] that increasing rate of N application increased yield and WUE where higher values were observed under N application rate of 150 kg ha⁻¹. Higher WUE at higher nitrogen doses was reported to be mainly due to higher grain yield of crops [45].

### TABLE 4: Pooled Mean of Main Effects of Irrigation and Nitrogen Rates on Grain and Straw Yield, Harvest Index, Water Used and Irrigation Water Use Efficiency (IWUE) in 2011/2012 and 2012/2013 Seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain Yield (kg ha⁻¹)</th>
<th>Straw Yield (kg ha⁻¹)</th>
<th>Harvest Index (%)</th>
<th>Total water used (m³ ha⁻¹)</th>
<th>IWUE (kg m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>I₁</td>
<td>4644.37</td>
<td>6106.25</td>
<td>43.39</td>
<td>15900.00</td>
<td>0.29</td>
</tr>
<tr>
<td>I₂</td>
<td>3677.97</td>
<td>5009.82</td>
<td>42.33</td>
<td>8268.00</td>
<td>0.45</td>
</tr>
<tr>
<td>I₃</td>
<td>1278.12</td>
<td>2865.09</td>
<td>30.81</td>
<td>5488.00</td>
<td>0.24</td>
</tr>
<tr>
<td>HSD(P≤0.05)</td>
<td>848.94</td>
<td>674.45</td>
<td>3.55</td>
<td>344.26</td>
<td>0.15</td>
</tr>
<tr>
<td>Nitrogen rates</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>N₀</td>
<td>2070.53</td>
<td>3686.35</td>
<td>33.83</td>
<td>10963.34</td>
<td>0.19</td>
</tr>
<tr>
<td>N₁</td>
<td>2931.60</td>
<td>4581.35</td>
<td>39.00</td>
<td>10963.34</td>
<td>0.27</td>
</tr>
<tr>
<td>N₂</td>
<td>3441.46</td>
<td>4892.79</td>
<td>40.53</td>
<td>10963.34</td>
<td>0.32</td>
</tr>
<tr>
<td>N₃</td>
<td>3724.30</td>
<td>5067.44</td>
<td>42.32</td>
<td>10963.34</td>
<td>0.34</td>
</tr>
<tr>
<td>HSD(P≤0.05)</td>
<td>1008.62</td>
<td>1005.62</td>
<td>3.89</td>
<td>NS</td>
<td>0.14</td>
</tr>
<tr>
<td>Interaction</td>
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</tr>
<tr>
<td>Irrigation x nitrogen rates</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>*</td>
</tr>
</tbody>
</table>

Where: I₁=4 days irrigation interval, I₂= 8 days irrigation interval, I₃= 12 days irrigation interval N₀= 0 kg N ha⁻¹, N₁= 50 kg N ha⁻¹, N₂ = 100 kg N ha⁻¹ and N₃ = 150 kg N ha⁻¹, HSD= Tukey Honesty Significant Difference. * = significant at 5% probability and NS = non-significant.

### TABLE 5: Interaction Effects of Irrigation Intervals and Nitrogen Rates on Grain and Straw Yield, Harvest Index and Irrigation Water Use Efficiency (IWUE) for the two seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain Yield (kg ha⁻¹)</th>
<th>Straw Yield (kg ha⁻¹)</th>
<th>Harvest Index (%)</th>
<th>IWUE (kg m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I₁N₀</td>
<td>2719.91</td>
<td>5529.07</td>
<td>37.68</td>
<td>0.18</td>
</tr>
<tr>
<td>I₁N₁</td>
<td>4689.02</td>
<td>6095.08</td>
<td>43.77</td>
<td>0.28</td>
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<tr>
<td>I₁N₂</td>
<td>5442.86</td>
<td>6335.6</td>
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<tr>
<td>I₁N₃</td>
<td>5725.67</td>
<td>6465.26</td>
<td>47.15</td>
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<td>I₂N₀</td>
<td>2360.15</td>
<td>4181</td>
<td>34.64</td>
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<td>I₂N₁</td>
<td>3572.93</td>
<td>4853.29</td>
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<tr>
<td>I₂N₂</td>
<td>3837.87</td>
<td>5285.16</td>
<td>44.92</td>
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<tr>
<td>I₂N₃</td>
<td>4452.92</td>
<td>5719.82</td>
<td>46.5</td>
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<tr>
<td>I₃N₀</td>
<td>1148.42</td>
<td>2283.08</td>
<td>29.32</td>
<td>0.16</td>
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<tr>
<td>I₃N₁</td>
<td>1295.4</td>
<td>2922.43</td>
<td>30.54</td>
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<tr>
<td>I₃N₂</td>
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<td>3175.06</td>
<td>31.11</td>
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<tr>
<td>I₃N₃</td>
<td>1326.2</td>
<td>3079.8</td>
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<td>0.28</td>
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<tr>
<td>HSD(P≤0.05)</td>
<td>912.32</td>
<td>1516.12</td>
<td>4.21</td>
<td>0.12</td>
</tr>
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</table>

Where: I₁=4 days irrigation interval, I₂= 8 days irrigation interval, I₃= 12 days irrigation interval, N₀= 0 kg N ha⁻¹, N₁= 50 kg N ha⁻¹, N₂ = 100 kg N ha⁻¹ and N₃ = 150 kg N ha⁻¹ and HSD= Tukey Honesty Significant Difference
Interaction of irrigation intervals and nitrogen level on irrigation water use efficiency was significant (Table 5). The maximum (0.55) value of IWUE was achieved in I₂N₃ treatment which was statistically at par with I₁N₂ while, the minimum (0.16) was with I₁N₀.

IV. CONCLUSION

Irrigation interval of 4 days in combination with 150kgN/ha nitrogen fertilizer gave the highest lowland rice yield in terms of grain, straw and harvest index with only 13% water saving. However, when irrigation interval of 8 days was applied, 48% water saving was achieved with 100kgN/ha which is significant in addition to reduced input costs. This therefore indicate that it is more profitable to adopt the 8 day irrigation interval in order to achieve the goal of minimizing water wastage and getting significant rice yield per hectare. Furthermore, the amount of water saved can be channeled to open more land for irrigation. Therefore 8 days irrigation interval and 100kg N ha⁻¹ is recommended for farmers in the study area.

REFERENCES


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