# EFFECTS OF IRRIGATION INTERVALS AND NITROGEN LEVELS ON PHYSIOLOGICAL GROWTH PARAMETERS OF RICE (*Oryza sativa* L.) VARIETIES IN DADIN KOWA, NORTHERN NIGERIA

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## ABSTRACT

*Rice is an important staple food for more than half of the world's population. Adequate nitrogen and irrigation management practices reduce nitrate leaching and ensure profitable yields. Field experiment were conducted during the dry seasons of 2014/2015, 2015/2016 and 2016/2017 at the Teaching and Research farm of the Federal College of Horticulture, Dadin Kowa, Northern, Nigeria to evaluate the effect of irrigation intervals and nitrogen levels on the physiological growth parameters of rice varieties. The experiment was designed as a 3 x 4 x 3 factorial experiment laid out in split-split plot arrangement replicated three times. The main plot consisted of three irrigation intervals (3, 6 and 9 days); the subplots four nitrogen levels (0, 60, 120 and 180 kg N/ha) while, the sub-sub plot comprised of three rice varieties (Faro 44, Faro 60 and Faro 61). Data collected in various parameters were subjected to analysis of variance (ANOVA) and means were separated using least significant difference at 5% probability level. Results showed that irrigation at every 6 days resulted in significantly higher physiological growth indices than other irrigation intervals. Nitrogen significantly, improved all the physiological parameters. High nitrogen level (180 kg N/ha) resulted in better performance than the control (0 kg N/ha). Varietal differences were also significant for most of the measured parameters. Faro 61 excelled in virtually all the physiological growth parameters while Faro 44 was the least. Nitrogen level and variety interactions indicating that Faro 61-applied 180 kg N/ha had higher values for leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR). In conclusion, Faro 61-applied 180 kg N/ha and irrigated every 6 days performed optimally in most of the physiological parameters and should be recommended for the farmers in Dadin Kowa, Northern Nigeria.*

***Key words:* growth, irrigation, nitrogen, physiology rice, varieties**

## INTRODUCTION

Rice has become the world most important cereal crop in the sense that more than half of the population of the world depends on it as a form of staple food (Sikuku *et al.*, 2012). Rice is the world's leading food crop, cultivated over an area of about 155 million hectares with a production of about 596 million tons of paddy (Vaughan *et al*., 2008). In terms of area and production, it is second to wheat. It provides about 22% of the world's supply of calories and 17% of the proteins (Jianguo *et al.*, 2003). Among the rice growing countries, India has the largest area (44.8 million ha) followed by China and Indonesia. With respect to production, India ranks 2nd with 131 million tons of paddy next to China which produces 200 million tons of paddy (FAOSTAT, 2010). Rice farming is the largest single use of land for food globally. It is the most important economic activity on earth. The crop is widely distributed in the humid tropics of Africa, South America, South and Southeast Asia and Oceania (Harris, 1996).

In Nigeria, more than half of the country's population relies on rice as the major daily source of calories. Nigeria was the largest producer of rice in West Africa and second largest producer in Africa after Egypt, with a total production of 4.833 million metric tonnes from 2.6 million hectares of land in 2013 (Danmaigoro, 2015). Demand for rice has increased in Nigeria at a faster rate than in any other West Africa countries since the mid of 1970s (Iwuchukwu *et al.*, 2017). The annual consumption demand for rice in Nigeria was about 7.9 million tonnes as at the middle of 2017 while local rice production was 6 million tonnes (Rice Farmers' Association of Nigeria, 2017).

Rice production requires large amounts of water. Most studies on constraints to high rice yield shows that water is the main factor for yield gaps and yield variability from experimental stations to farm (Papademetriou, 2001; Akinbile, 2010). Availability of water in the crop root zone is very essential for transpiration and tissue formation. Various studies have reported inconsistent growth and yield of NERICA rice varieties under various soil water conditions (Bouman et al., 2007; Matsumoto *et al*., 2014; Kikuta *et al*., 2016). Longer irrigation interval resulted in reduced tissue formation due to decrease in nutrients and water uptake (Husseini *et al*., 2002).

Nitrogen is the kingpin in any performance to increase agricultural production. It is the most limiting nutrient for rice growth and yield in almost all environments (Oikeh *et al*., 2009). One major consequence of inadequate N is reduced leaf area, thereby limiting light interception, photosynthesis and finally biomass growth, grain yield and water productivity (Sinclair, 1990).

Application of appropriate quantity of N at the right time using the right irrigation interval will increase yield and N use efficiency (Rezaei *et al.*, 2009; Bagayoko *et al*., 2010). This will not only save the environment but also reduces the production cost thereby increasing farmers' income. Yield is a complex feature which depends on the function of physiological combined processes in particular, the limiting components that change with the cultivar. Identification of growth physiological indices in the analysis of factors affecting yield and its components has a great importance and its stability determines the dry matter production which is a criterion of yield components. Thus, in this regard leaf area index (LAI), total dry weight (TDW) and leaf dry weight (LDW) should be measured in periodic intervals during the growing season (Azarpour *et al*., 2014). Also crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area duration (LAD), leaf area rate (LAR), leaf weight rate (LWR) and specific leaf area (SLA) are indices often used for evaluation of plant productivity, capability and environmental efficiency (Anzoua *et al*., 2010). Nitrogen nutrition due to the considerable impact on growth parameters and physiological traits of rice is important. The percentage of light penetration, photosynthesis active radiation, light use efficiency, dry matter partitioning to different parts are affected by the amount of nitrogen. Dry matter partitioning to the reproductive organs depends on number, capacity and activity of physiological sinks (Fageria and Baligar, 2001; Fageria and Baligar, 2005; Fageria, 2007). The cultivar of rice with higher physiological indices has better growth and higher yield (Azarpour *et al*., 2014). Thus, this study therefore evaluates the effects of irrigation intervals and nitrogen levels on physiological growth parameters of rice varieties in Dadin Kowa, a location in the Northern part of Nigeria.

## MATERIALS AND METHODS

Field experiments were conducted during the dry seasons (October to March) of 2014/2015, 2015/2016 and 2016/2017 at the Teaching and Research farm of the Federal College of Horticulture, Dadin Kowa, Gombe State in Northern Nigeria (Latitude 11° 30' N, Longitude 10° 20' E and 240 m above sea level) located in the Sudan Savanna Agro-ecological zone of Nigeria. The mean temperature ranges from 30 to 33 °C. The rainfall pattern is unimodal, ranging from 700 to 1250 mm and is characterized by distinct dry (October – May) and rainy (June – September) seasons (Mustapha *et al*., 2010). Soil samples were collected, using soil auger, from the experimental site at the depth of 0-20 cm prior to crop establishment each season. The samples were air dried, bulked and sieved for determination of physical and chemical characteristics of the soil in the experimental site.

The land was ploughed and harrowed using animal-drawn emcot plough and harrow respectively. The seeds were initially raised in nursery beds of 1.3 $m^2$ dimension and transplanted to the main fields 4 weeks later at a spacing of 20 x 20 cm and at two seedlings per hole.

Meanwhile, field layout was done to mark out the appropriate number of treatment sub-sub plots, each measuring 1.5 x 1.2 m prepared manually. The study was designed as a 3 x 4 x 3 factorial experiment laid out in split-split plots arrangements with three replications. Irrigation interval constituted the main plots, nitrogen levels sub-plots while rice varieties were in the sub-sub plots. Surface irrigation method was used in conveying water into each basin. The canals were lined with polyethylene sheet to reduce the rate of seepage and allow free flow. The irrigation water discharge into the basins were computed and the depth of water applied was monitored using a stop watch. The timed volume-container head method (bucket system) was employed during each irrigation scenario in calculating the amounts of water applied into required depth using the formula of Trimmer (1994): $D = V/T$

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).

The flow rate and the average time allowed to pond a basin were calculated.

Thereafter, irrigation treatments were applied as the main plot factor as I = 3 days, $I_2$ = 6 days and 9 days irrigation intervals. The sub plots were made up of four levels of nitrogen 0, 60, 120 and 180 kg N/ha while the sub sub-plots were three rice varieties (FARO 44, FARO 60, and FARO 61) obtained from the seed unit of National Cereal Research Institute, Badeggi, Niger State, Nigeria. Base application of phosphorus and potassium was carried out at 60 kg/ha using single super phosphate (18 % $P_2O_5$) and muriate of potash (60 % $K_2O$) on all plots. Glyphosate herbicide was applied after land preparation, two weeks before transplanting at the rate of 2.88 kg $ha^{-1}$ (a.i.) at 150 ml in 20 liters of water to control weeds comprising mostly sedges and grasses with rhizomes. Two weeks after transplanting, post-emergence herbicide, 2, 4-D amine (2.4 kg/ha a.i.) plus Propan 360 (propanil 1.5 kg/ha a.i.) were applied at the rate of 250 ml in 20 liters of water. In addition, two manual weeding were carried out using traditional hoe at 3 and 6 weeks after transplanting (WAT). Three consecutive rice plants were tagged per plot for data collection. Data collected included leaf area index (LAI) at 12 weeks after transplanting (WAT) and at harvest. Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were computed using the appropriate formula as suggested by Harper (1999).

$$\text{LAI} = \frac{\text{sum of leaf area/hill of all leaves (cm}^2\text{)}}{\text{area of land covered by the leaves (cm}^2\text{)}}$$

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1}$$

$$\text{RGR} = \frac{\text{In } W_2 - \text{In } W_1}{t_2 - t_1}$$

Where $W_1$ and $W_2$ represent the weights at two-time intervals $t_1$ and $t_2$

$$\text{NAR} = \frac{(W_2 - W_1)\ (\text{In } LA_2 - \text{In } LA_1)}{(LA_2 - LA_1)\ (t_2 - t_1)}$$

Where $LA_1$ and $LA_2$ represent leaf areas at time intervals $t_1$ and $t_2$, while $W_1$ and $W_2$ represent weights at the two-time intervals.

All the data collected on various parameters were subjected to statistical analysis of variance using Genstat Discovery Edition 2013 statistical package. Means were separated using Least Significant Difference (LSD) test at $P \leq 0.05$ (Steel *et al*., 1997). The results of the main effects were presented and discussed except if there were significant interactive effects.

**RESULTS**

The soil of the experimental site was silty loam, slightly acidic, low in organic carbon, nitrogen and phosphorus (Table 1). Exchangeable bases and micronutrients are moderate. The main effects of irrigation intervals, nitrogen levels and varieties on LAI for 2015, 2016 and 2017 are presented on Table 2. Irrigation intervals showed significant effect ($p \leq 0.05$) on leaf area index (LAI) only at harvest in 2015 season. Irrigation at every 6 days gave highest value of LAI (2.178) followed by 3 days irrigation interval with value of 1.535 while irrigation at every 9 days gave the lowest LAI (1.362). There was no significant difference in irrigation intervals on LAI in 2016 and 2017 seasons.

**TABLE 1: PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL AT THE EXPERIMENTAL SITE FOR 2015, 2016 AND 2017 DRY SEASONS**

| **Parameters** | **Values** | | |
|---|---|---|---|
| | **2015** | **2016** | **2017** |
| pH water | 6.47 | 6.62 | 6.80 |
| pH KCl | 5.51 | 5.71 | 5.61 |
| Organic Carbon (g/kg) | 1.18 | 1.84 | 1.97 |
| Total Nitrogen (g/kg) | 0.16 | 0.12 | 0.12 |
| Available P. (mg/kg) | 8.87 | 8.31 | 9.22 |
| **Exchangeable bases (cmol/kg)** | | | |
| Calcium | 3.11 | 3.64 | 4.80 |
| Magnesium (Mg) | 0.89 | 0.78 | 0.74 |
| Potassium (K) | 0.29 | 0.29 | 0.36 |
| Sodium (Na) | 0.20 | 0.12 | 0.48 |
| **Micro nutrients (mg/kg)** | | | |
| Zinc | 1.54 | 0.63 | 1.09 |
| Copper | 0.86 | 0.41 | 0.64 |
| Iron | 6.11 | 7.36 | 6.74 |
| Manganese | 13.63 | 18.24 | 15.94 |
| **Soil Texture (%)** | | | |
| Sand | 24.40 | 24.04 | 26.00 |
| Silt | 51.28 | 52.34 | 51.00 |
| Clay | 24.32 | 23.62 | 23.00 |
| Textural Class | SL | SL | SL |

SL = Silty Loam

Nitrogen levels had highly significant ($p \leq 0.01$) effect on LAI throughout the sampled periods in 2015, 2016 and 2017 seasons (Table 2). At 2015 season, rice plants that received nitrogen application of 180 kg N/ha produced highest values of LAI at 12 WAT and at harvest (4.862 and 3.329 respectively). The least values of LAI of 1.342 and 0.652 were recorded at 12 WAT and at harvest from plots without nitrogen fertilization. Similarly, in 2016 rice plants that received nitrogen fertilizer at 180 kg N/ha produced highest values of LAI at 12 WAT and at harvest (5.03 and 3.98, respectively). The lowest values of LAI were recorded from plants without nitrogen fertilization at 12 WAT and at harvest. The trend was similar to that of 2016 and 2017 seasons. Higher values of LAI were recorded from plants that received nitrogen application of 180 kg N/ha in 2017 season with mean values of 7.170 and 4.530 at 12 WAT and at harvest while smallest values of 1.448 and 1.423 at 12 WAT and at harvest, respectively.

**TABLE 2: EFFECT OF IRRIGATION INTERVALS, NITROGEN LEVELS AND VARIETAL DIFFERENCES ON LEAF AREA INDEX (LAI) IN 2015, 2016 AND 2017 DRY SEASONS**

| | 2015 | | 2016 | | 2017 | |
|---|---|---|---|---|---|---|
| **Treatment** | **12WAT** | **HAV** | **12WAT** | **HAV** | **12WAT** | **HAV** |
| Irrigation intervals (days) (I) | | | | | | |
| 3 | 3.33 | 1.54 | 2.78 | 1.97 | 4.54 | 3.04 |
| 6 | 3.19 | 2.18 | 2.89 | 2.23 | 3.18 | 3.02 |
| 9 | 2.41 | 1.36 | 2.54 | 1.98 | 3.01 | 2.35 |
| **P of F** | **0.110** | **0.050** | **0.620** | **0.440** | **0.090** | **0.543** |
| **LSD** | **0.963** | **0.640** | **0.963** | **0.578** | **0.811** | **4.073** |
| Nitrogen levels(kg/ha) (N) | | | | | | |
| 0 | 1.34 | 0.65 | 1.13 | 0.66 | 1.45 | 1.42 |
| 60 | 2.35 | 1.09 | 1.96 | 1.42 | 2.31 | 2.24 |
| 120 | 3.35 | 1.69 | 2.81 | 2.22 | 3.26 | 3.13 |
| 180 | 4.86 | 3.33 | 5.03 | 3.98 | 7.17 | 4.53 |
| **P of F** | **0.001** | **0.001** | **0.001** | **0.001** | **0.001** | **0.003** |
| **LSD** | **0.262** | **0.374** | **0.430** | **0.520** | **0.296** | **2.921** |
| Varieties (V) | | | | | | |
| FARO 44 | 2.49 | 1.36 | 2.16 | 1.63 | 2.45 | 2.55 |
| FARO 60 | 2.97 | 1.65 | 2.61 | 2.00 | 2.84 | 3.04 |
| FARO 61 | 3.47 | 2.06 | 3.43 | 2.55 | 3.28 | 4.97 |
| **P of F** | **0.001** | **0.001** | **0.001** | **0.001** | **0.001** | **0.092** |
| **LSD** | **0.082** | **0.126** | **0.223** | **0.153** | **0.087** | **2.300** |
| Interactions | | | | | | |
| I x N | NS | NS | NS | NS | NS | NS |
| I x V | NS | NS | NS | NS | NS | NS |
| N x V | ** | NS | ** | NS | ** | NS |
| I x N x V | NS | NS | NS | NS | NS | NS |

WAT = weeks after transplanting; HAV = harvest; P of F = Probability F value; LSD = least significant difference; ** denotes significant at 1% probability level; NS denotes not significant.

There were highly significant ($p \leq 0.01$) differences among the varieties on LAI in 2015, 2016 and 2017 seasons throughout the sampled periods as shown on Table 2. In 2015 season, Faro 61 recorded the highest values of LAI of 3.471 and 2.063 at 12 WAT and at harvest, respectively, while Faro 44 had the smallest values of 2.488 and 1.360 at 12 WAT and at harvest, respectively. Similar trends were observed in 2016 and 2017 seasons.

**TABLE 3: INTERACTION BETWEEN NITROGEN LEVELS AND VARIETAL DIFFERENCES ON LEAF AREA INDEX AT 12 WEEKS AFTER TRANSPLANTING IN 2015, 2016 AND 2017 DRY SEASONS**

| | Nitrogen Levels (Kg N/ha) | | | |
|---|---|---|---|---|
| **Varieties** | **0** | **60** | **120** | **180** |
| | | **2015** | | |
| Faro 44 | 1.011 | 1.951 | 2.994 | 3.995 |
| Faro 60 | 1.368 | 2.385 | 3.346 | 4.786 |
| Faro 61 | 1.647 | 2.726 | 3.707 | 5.805 |
| P of F | | 0.001 | | |
| LSD within nitrogen levels | | 0.164 | | |
| LSD across nitrogen levels | | 0.289 | | |
| | | **2016** | | |
| Faro 44 | 0.427 | 1.207 | 1.911 | 2.970 |
| Faro 60 | 0.632 | 1.396 | 2.188 | 3.767 |
| Faro 61 | 0.920 | 1.654 | 2.567 | 5.060 |
| P of F | | 0.001 | | |
| LSD within nitrogen levels | | 0.306 | | |
| LSD across nitrogen levels | | 0.565 | | |
| | | **2017** | | |
| Faro 44 | 1.119 | 2.046 | 2.825 | 3.793 |
| Faro 60 | 1.469 | 2.309 | 3.131 | 4.443 |
| Faro 61 | 1.756 | 2.565 | 3.427 | 5.355 |
| P of F | | 0.001 | | |
| LSD within nitrogen levels | | 0.173 | | |
| LSD across nitrogen levels | | 0.323 | | |

Significant interaction was observed between nitrogen fertilizer levels and varieties at 12 WAT in 2015, 2016 and 2017 dry seasons. Faro 61 under 180 kg N/ha recorded the highest LAI values of 5.805, 5.060 and 5.355 in 2015, 2016 and 2017 seasons, respectively while Faro 44 without nitrogen fertilization gave the least values of 1.011, 0.427 and 1.119 in 2015, 2016 and 2017 seasons respectively (Table 3). LAI increased as nitrogen fertilizer rate increased from 0 to 180 kg N/ha in all the varieties.

**TABLE 4: EFFECT OF IRRIGATION INTERVALS, NITROGEN LEVELS AND VARIETAL DIFFERENCES ON CROP GROWTH RATE (CGR), RELATIVE GROWTH RATE (RGR) AND NET ASSIMILATION RATE (NAR) BETWEEN 4 AND 8 WAT**

| Treatment | CGR | | | RGR | | | NAR | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2015** | **2016** | **2017** | **2015** | **2016** | **2017** | **2015** | **2016** | **2017** |
| Irrigation intervals (I) (days) | | | | | | | | | |
| 3 | 0.094 | 0.082 | 0.064 | 0.064 | 0.036 | 0.070 | 9.472 | 8.213 | 7.217 |
| 6 | 0.095 | 0.085 | 0.070 | 0.071 | 0.038 | 0.071 | 9.686 | 9.326 | 7.900 |
| 9 | 0.057 | 0.100 | 0.062 | 0.047 | 0.039 | 0.065 | 6.395 | 10.942 | 7.213 |
| **P of F** | **0.047** | **0.614** | **0.620** | **0.042** | **0.576** | **0.712** | **0.050** | **0.481** | **0.787** |
| **LSD** | **0.031** | **0.050** | **0.022** | **0.017** | **0.006** | **0.020** | **2.886** | **3.995** | **3.080** |
| Nitrogen levels (kg/ha) | | | | | | | | | |
| 0 | 0.041 | 0.043 | 0.026 | 0.064 | 0.035 | 0.063 | 6.966 | 5.565 | 5.159 |
| 60 | 0.063 | 0.068 | 0.043 | 0.061 | 0.037 | 0.064 | 7.894 | 8.276 | 6.017 |
| 120 | 0.088 | 0.099 | 0.072 | 0.059 | 0.039 | 0.073 | 8.662 | 10.428 | 8.154 |
| 180 | 0.136 | 0.145 | 0.120 | 0.059 | 0.040 | 0.075 | 10.548 | 11.040 | 10.445 |
| **P of F** | **0.001** | **0.001** | **0.001** | **0.228** | **0.107** | **0.118** | **0.001** | **0.006** | **0.001** |
| **LSD** | **0.010** | **0.015** | **0.013** | **0.006** | **0.005** | **0.012** | **1.169** | **1.042** | **1.833** |
| Variety (V) | | | | | | | | | |
| FARO 44 | 0.070 | 0.078 | 0.055 | 0.060 | 0.037 | 0.068 | 8.026 | 8.832 | 6.901 |
| FARO 60 | 0.080 | 0.087 | 0.063 | 0.061 | 0.038 | 0.068 | 8.417 | 8.599 | 7.241 |
| FARO 61 | 0.096 | 0.101 | 0.078 | 0.062 | 0.038 | 0.069 | 9.109 | 9.051 | 8.189 |
| **P of F** | **0.001** | **0.001** | **0.001** | **0.082** | **0.493** | **0.844** | **0.001** | **0.720** | **0.019** |
| **LSD** | **0.004** | **0.006** | **0.008** | **0.002** | **0.002** | **0.005** | **0.476** | **0.118** | **0.912** |
| Interactions | | | | | | | | | |
| I x N | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| I x V | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| N x V | NS | NS | NS | ** | NS | NS | NS | NS | NS |
| I x N x V | NS | NS | NS | NS | NS | NS | NS | NS | NS |

CGR = crop growth rate; RGR = relative growth rate; NAR = net assimilation rate

The effects of irrigation intervals, nitrogen levels and varietal differences on CGR for 2015, 2016 and 2017 seasons are presented on Table 4. There were significant effects of irrigation intervals on CGR in 2015 season only.

Rice plants irrigated at every 6 days recorded highest CGR of 0.095 g/cm$^2$/day which was statistically at par with those irrigated at every 3 days (0.094 g/cm$^2$/day) while those on 9 days irrigation regime had the lowest CGR (0.057 g/cm$^2$/day). Nitrogen fertilizer rates on the other hand had highly significantly ($p \leq 0.01$) effects on CGR in the three seasons. Plants that received 180 kg N/ha recorded highest values of CGR at 0.136, 0.145 and 0.120 g/cm$^2$/day in 2015, 2016 and 2017 seasons, respectively while the control (0 kg N/ha) had the least values of 0.041, 0.043 and 0.026 $g/cm^2/day$ in 2015, 2016 and 2017 seasons, respectively. There were highly significant effects of varieties on CGR in all the seasons. Faro 61 recorded highest values of CGR at 0.096, 0.101 and 0.078 $g/cm^2/day$ in 2015, 2016 and 2017 seasons, respectively while the least values of 0.070, 0.078 and 0.055 $g/cm^2/day$ were obtained from Faro 44 in 2015, 2016 and 2017 seasons, respectively.

**TABLE 5: MEAN VALUES INTERACTION BETWEEN NITROGEN LEVELS AND VARIETIES FOR RGR AT 2015 DRY SEASON**

| | **Varieties** | | |
|---|---|---|---|
| **Nitrogen levels (Kg/ha)** | **FARO 44** | **FARO 60** | **FARO 61** |
| 0 | 0.058 | 0.056 | 0.059 |
| 60 | 0.060 | 0.061 | 0.060 |
| 120 | 0.060 | 0.059 | 0.060 |
| 180 | 0.059 | 0.066 | 0.068 |
| P of F | | 0.003 | |
| LSD (0.05) within nitrogen levels | | 0.004 | |
| LSD (0.05) across nitrogen levels | | 0.007 | |

The results on the effect of irrigation intervals, nitrogen levels and varietal differences on RGR for 2015, 2016 and 2017 seasons are presented on Table 4. The effects of irrigation intervals on RGR were significant only in 2015 season. Irrigation interval of 6 days recorded highest value of RGR (0.071), while 9 days irrigation regime had the least RGR (0.047). Results on the effect nitrogen fertilization on RGR were not significant ($p \leq 0.05$). Varietal differences showed highly significant ($p \leq 0.01$) on RGR in all the years. Faro 61 recorded highest values of RGR with 0.082, 0.493 and 0.844 in 2015, 2016 and 2017 seasons, respectively while the least values of 0.060, 0.037 and 0.068 were obtained from Faro 44 in 2015, 2016 and 2017 seasons, respectively. There was significant interaction between nitrogen levels and varieties on RGR in 2015 (Table 5). Faro 61 applied with 180 kg N/ha recorded highest value of RGR (0.068 g/g/day) while the least value was obtained from combination of Faro 60 and 0 kg N/ha with RGR value of 0.056 g/g/day.

The results of the effects of irrigation intervals, nitrogen levels and varietal differences on NAR for the three years are presented in Table 4. Results of the effect of irrigation intervals on NAR were not statistically significant in all the three years. However, the effect of nitrogen fertilization on NAR was highly significant ($p \leq 0.01$) in the three years.

Plants that received 180 kg N/ha had the highest values of NAR with 10.548, 21.040 and 10.445 $cm^2/g/day$ in 2015, 2016 and 2017 seasons, respectively, while application of 0 kg N/ha gave the least values of 6.966, 15.565 and 5.159 $cm^2/g/day$ in 2015, 2016 and 2017 seasons, respectively. Results of the effects of varietal differences on NAR were significant in 2015 and 2017 seasons. In 2015 and 2017 seasons, Faro 61 recorded highest values of 9.109 and 8.189 $cm^2/g/day$ respectively, while Faro 44 had the least values of 8.026 and 6.901 $cm^2/g/day$ in 2015 and 2017 seasons, respectively.

The effects of irrigation intervals, nitrogen levels and varietal differences on CGR between 8 and 12 WAT for all the years are indicated in Table 6. The effects of irrigation intervals on CGR was not statistically significant in 2015 and 2016 seasons but significant ($p \leq 0.05$) in 2017. Irrigation at every 6 days had the highest CGR value of 0.202 $g/cm^2/day$ while 9 days irrigation regime had the least (0.088 $g/cm^2/day$). The effects of nitrogen fertilizer rates on CGR was highly significant ($p \leq 0.01$) in 2015, 2016 and 2017 seasons. In all the three years trials, plants that received highest nitrogen rate of 180 kg N/ha recorded highest values of CGR at 0.095, 1.460 and 0.232 $g/cm^2/day$ in 2015, 2016 and 2017 seasons, respectively. The least values were obtained from plants without application of nitrogen fertilizer with CGR values of 0.048, 0.459 and 0.088 $g/cm^2/day$ in 2015, 2016 and 2017 seasons, respectively.

**TABLE 6: EFFECT OF IRRIGATION INTERVALS, NITROGEN LEVELS AND VARIETAL DIFFERENCES ON CROP GROWTH RATE (CGR), RELATIVE GROWTH RATE (RGR) AND NET ASSIMILATION RATE (NAR) BETWEEN 8 AND 12 WAT**

| Treatment | CGR | | | RGR | | | NAR | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 |
| Irrigation intervals (I) (days) | | | | | | | | | |
| 3 | 0.059 | 0.898 | 0.170 | 0.019 | 0.077 | 0.048 | 5.222 | 9.958 | 12.472 |
| 6 | 0.070 | 0.994 | 0.202 | 0.021 | 0.074 | 0.045 | 6.177 | 9.654 | 13.540 |
| 9 | 0.087 | 0.921 | 0.088 | 0.031 | 0.070 | 0.030 | 8.507 | 9.647 | 6.512 |
| P of F | 0.060 | 0.797 | 0.044 | 0.114 | 0.622 | 0.047 | 0.078 | 0.942 | 0.029 |
| LSD | 0.023 | 0.401 | 0.084 | 0.013 | 0.017 | 0.014 | 2.903 | 3.669 | 4.742 |
| Nitrogen levels (kg/ha) | | | | | | | | | |
| 0 | 0.048 | 0.459 | 0.088 | 0.009 | 0.071 | 0.035 | 2.931 | 7.496 | 8.853 |
| 60 | 0.080 | 0.813 | 0.129 | 0.018 | 0.078 | 0.038 | 4.925 | 10.170 | 10.287 |
| 120 | 0.065 | 1.019 | 0.166 | 0.027 | 0.074 | 0.044 | 7.302 | 10.060 | 11.300 |
| 180 | 0.095 | 1.460 | 0.232 | 0.040 | 0.073 | 0.046 | 11.384 | 10.616 | 12.925 |
| P of F | 0.001 | 0.001 | 0.001 | 0.001 | 0.141 | 0.020 | 0.001 | 0.001 | 0.001 |
| LSD | 0.013 | 0.095 | 0.029 | 0.004 | 0.006 | 0.007 | 0.981 | 1.754 | 1.646 |
| Variety (V) | | | | | | | | | |
| FARO 44 | 0.075 | 0.773 | 0.134 | 0.028 | 0.071 | 0.041 | 7.709 | 8.862 | 10.110 |
| FARO 60 | 0.071 | 0.913 | 0.153 | 0.023 | 0.075 | 0.042 | 6.485 | 9.727 | 10.885 |
| FARO 61 | 0.069 | 0.127 | 0.174 | 0.020 | 0.076 | 0.039 | 5.712 | 10.670 | 11.529 |
| P of F | 0.239 | 0.001 | 0.001 | 0.001 | 0.003 | 0.190 | 0.001 | 0.001 | 0.014 |
| LSD | 0.007 | 0.078 | 0.014 | 0.002 | 0.003 | 0.003 | 0.483 | 1.232 | 0.934 |
| Interactions | | | | | | | | | |
| I x N | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| I x V | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| N x V | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| I x N x V | NS | NS | NS | NS | NS | NS | NS | NS | NS |

The values of RGR in 2015 and 2016 seasons were not significantly affected by irrigation intervals but were significantly (p≤0.05) affected in 2017 season (Table 6). Irrigation interval of every 3 days produced plants with highest value of RGR at 0.048 g/g/day while 9 days irrigation regime had the least value of RGR (0.030 g/g/day). The effect of nitrogen fertilization was highly significant in 2015 and 2017 seasons. In both seasons, plants applied 180 kg N/ha recorded highest values of RGR while those with 0 kg N/ha had the least values. The effect of varietal differences on RGR was significant in 2015 and 2016 seasons. In 2015, Faro 44 recorded the highest value of RGR at 0.028 g/g/day while Faro 61 had the least value (0.020 g/g/day). In 2016 however, Faro 60 had the highest value of RGR (0.042 g/g/day) while Faro 61 gave the least value (0.039 g/g/day).

**TABLE 7: LINEAR CORRELATION AMONG PHYSIOLOGICAL GROWTH PARAMETERS**

| | WK12 LAI | HVLAI | CGR | RGR | NAR |
|---|---|---|---|---|---|
| **WK12 LAI** | 1 | 0.440** | 0.025ns | -0.398** | -0.151** |
| **HVLAI** | 0.440** | 1 | -0.119* | -0.005ns | 0.079ns |
| **CGR** | 0.025ns | -0.119* | 1 | -0.060ns | 0.080ns |
| **RGR** | -0.398** | -0.005ns | -0.060ns | 1 | 0.832** |
| **NAR** | -0.151** | 0.079ns | 0.080ns | 0.832** | 1 |

WK12LAI=Leaf area index at 12 weeks after transplanting, HVLAI=LAI at harvest; CGR= crop growth rate; RGR=relative growth rate; NAR=net assimilation rate.

The effects of irrigation intervals on NAR was significant (p≤0.05) only in 2017 season as presented in Table 6. Irrigation every 6 days produced highest NAR value of 13.540 $cm^2$/g/day while 9 days irrigation regime had the least (6.512 $cm^2$/g/day). Nitrogen fertilization effect on NAR was significant in all the three years. Highest values of NAR were recorded on plants applied with 180 kg N/ha in all the seasons while least values of NAR were from plants without nitrogen. The effects of varieties on NAR was also significant in the three years (Table 6). In 2015 season, Faro 44 recorded highest NAR value of 7.709 $cm^2$/g/day while Faro 61 had the least (5.712). In 2016 and 2017 seasons, Faro 61 produced highest NAR values of 10.690 and 11.529 $cm^2$/g/day in 2016 and 2017 seasons respectively while Faro 44 had the least values of 8.86 and 10.11 $cm^2$/g/day in 2016 and 2017 seasons. Results of the simple linear correlation among the physiological growth indices revealed that WK12LAI shows significant positive relationship with HVLAI and significant negative relationship with RGR and NAR but no significant relationship with CGR (Table 7). HVLAI shows significant negative relationship with CGR but no significant relationship with RGR and NAR. CGR shows no significant relationship with RGR and NAR while RGR had significant positive relationship with NAR.

## DISCUSSION

The high leaf area index (LAI) at harvest in 2015 from the irrigation interval of every 3 and 6 days could be due to the effect of water on activation of the cell division and elongation (Abul-El-Ezz, 2014). The low values of LAI at the irrigation interval of every 9 days could be due to water stress which leads to decrease rate of leaf initiation and reduced leaf area of already formed leaves leading to reduced photosynthetic activity in the affected leaves. In rice, erect leaves have a higher leaf area index that increases photosynthetic carbon assimilation rate through light capture and nitrogen use efficiency (Sinclair and Sheehy, 1999; Sakamoto *et al*., 2006). Leaves are the predominant photosynthetic organ and thus, are critical targets for maximizing carbon assimilation by improving morphological traits (Zhu *et al*., 2010).

Furthermore, the available nutrients coupled with available moisture might have helped in enhancing leaf area, which thereby resulted in higher photo-assimilates and more dry matter accumulation. These results are supported by the earlier findings of Swarup and Yaduvanshi, (2000), Gewaily (2006) and Yadana *et al*. (2009) who reported that adequate nitrogen and moisture in rice enhance leaf area and dry matter production.

The variation in LAI was also an indication of increased water application resulting in decreased crop water use since water stress had been eliminated hence the better leaves orientation during the ripening stage. This agrees with the findings of Nwadukwe and Chude (1998) and Lafittee *et al*. (2004, 2007) who reported that LAI is a function of water application.

Furthermore, the significant response of LAI to higher rates of nitrogen may be an indication that nitrogen was taken up by the plant and subsequently utilized in cell multiplication, amino acids synthesis and energy formation that acts as structural compound of the chloroplast which carries out the photosynthesis (Ng'etich *et al*., 2013). Nitrogen has been reported to be a constituent of chlorophyll (Lawlow, 2002). However, nitrogen insufficiency has been reported to reduce individual LA, LAI and total LAI resulting in reduced surface light interception for photosynthesis (Azarpour *et al*., 2014). Josiah *et al*. (2007) attributed the increase in leaf area of cucumber to peculiar consumptive use nutrients especially nitrogen in the soil. The high values of RGR from irrigation intervals of every 3 days under high nitrogen fertilization and the high values of crop growth rate (CGR), net assimilation rate (NAR) in three years' trials at irrigation intervals of 6 days is in line with the report of Azarpour *et al*. (2014) who showed that increased nitrogen application increased NAR and CGR. Also, increased CGR with increased nitrogen supply was in line with the observation of Akintoye (1995) who reported that adequate nitrogen application in rice enhance dry matter production.

Low values observed with long irrigation interval and low or zero nitrogen fertilization can be attributed to water stress. This result agreed with findings of Abayomi and Adedoyin (2004) who found low values for CGR and RGR at low or zero nitrogen application in water stressed maize.

## CONCLUSION

The study evaluated the effect of irrigation intervals and nitrogen levels on physiological growth parameters of three rice varieties in

Dadin Kowa, Northern Nigeria. Irrigation interval of 6 days performed better in most of the physiological growth indices of rice. Nitrogen significantly increased physiological growth indices evaluated with increasing levels up to 180 kg N/ha. Faro 61 consistently performed better in virtually all the physiological growth indices. Thus 6 days irrigation interval, 180 kg N/ha and Faro 61 is recommended.

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