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RESEARCH ARTICLE

EFFECT OF IRRIGATION DEFICIT AND NITROGEN FERTILIZATION ON THE UPTAKE OF NITROGEN AND GRAIN YIELD OF RICE IN ADAMAWA STATE, NIGERIA

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ABSTRACT

Water and Nitrogen deficiency are the most important yield limiting factor in rice production. The effect of various irrigation regimes and nitrogen fertility levels on lowland rice (FARO 44) and soil properties aimed at improving water and nitrogen use efficiency was studied for two years during the dry seasons of 2011/2012 and 2012/2013 in the field at the Lake Geriyo Irrigation scheme farms, Yola, Adamawa State, Nigeria. Six Irrigation regimes involving three irrigation intervals (4, 8 and 12 days intervals referred to as I_1, I_2 and I_3 respectively) and three irrigation withholding at different growth stages (vegetative, reproductive and repining stage referred to as I_4, I_5 and I_6 respectively) with four nitrogen fertility levels (0, 50, 100 and 150kg N ha^{-1} referred to as N_0, N_1, N_2 and N_3 respectively) were imposed in a split plot design, replicated three times. The results showed that grain yield, N concentration in grain and straw and uptake were higher in 4 days irrigation interval and 150 kg N ha^{-1} treatments (I_1N_3). Higher agronomic nitrogen use efficiency (24.85 kg kg^{-1}) was recorded in I_2N_1 treatments and partial factor productivity of nitrogen (93.78 kg kg^{-1}) under I_1N_1 treatments. N uptake increased with increased in the N application levels. It can be concluded that rice may be grown on clay loam soils of Adamawa State, with irrigation interval of between 4 to 8 days and irrigation withholding at ripening stage with 100 – 150kg N ha^{-1} to achieve higher N uptake and yield.

INTRODUCTION

Nitrogen is the single most important production input, and it is most limiting nutrient for flooded or lowland rice production worldwide (Fageria and Baligar, 2001). Making accurate N recommendations for higher N demanding crops like lowland rice is becoming more important as concern growth about the high cost of this input and nitrate pollution of surface and ground waters in agricultural areas (Fageria and Baligar, 1999). Nitrogen is normally a key factor in achieving optimum lowland rice grain yields (Fageria *et al.*, 2003). Sharma and De Datta (1985) reported that components of yield are closely associated with the nitrogen supply at each growth period. Moreover, active absorption and metabolism of nitrogen results in a large increase in dry weight, tillering, height and leaf area. Nitrogen (N) is essential for rice, and usually the most yield-limiting nutrient in irrigated rice production around the world (Samonte *et al.,* 2006).Most of the rice soils of the world are deficient in N (Hashem, 2001). De Datta (1978) reported that the recovery of applied N by wetland rice was between 30 and 40% and in some cases even less. Even with good agronomic practices, similar low recovery in the tropics was observed (Prasad and De Datta, 1979). Nigerian soils are generally low in fertility, organic matter and soil nutrients supplies are in the deficit ranging from 33.33 to 83.4% in sole crops and 39.6 to 88.9% in mix crops (Jones and Wild, 1975 and Singh, 1997). Thus, the deficiency of nitrogen has before now, been identified as the single most serious nutritional problem of rice (Narteh and Sahrawat, 1999). In addition, due to intensification of rice production in the lowlands of northern guinea savannah, with minimal use of fertilizers, the soils that are generally low in organic carbon with widespread deficiency in nitrogen are further depleted (Olaleye *et al.*, 2008).

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N fertilizers upon application to soil are subjected to numerous reactions, transformations and loss mechanisms such as NH_3, nitrification and subsequent denitrification, leaching, chemical and microbial immobilization and surface runoff (Takamura *et al.,* 1977). Thus quite a high proportion of the applied N is lost one way or the other (Shah *et al*., 1993). N use efficiency (NUE) was defined as the ratio of grain yield with N application minus grain yield without N application to N application and was used to describe the capability of yield increase per kilogram pure N and added that nitrogen use efficiency generally take into account quantity of N accumulated in the plant, known as uptake efficiency and quantity of N utilized in grain production known as utilization efficiency (Tayefe *et al.*, 2011). As a result, N use efficiency for crop production is discouragingly low. In view of these and high cost of nitrogen fertilizer, it is important to improve the N utilization efficiency for crop production with the objective to increase crop productivity and reduce cost of production. Therefore, well managed fertilizer at farm level can increase cropping intensity, yield per hectare, nutrient use efficiencies and eventually generate more income. The study was undertaken with the aim of identifying the nitrogen uptake of irrigated rice as influenced by the irrigation regimes and nitrogen fertilization.

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). The experiments were carried out at the Lake Geriyo Irrigation scheme site, west of River Benue and north of Jimeta-Yola town, the Capital of Adamawa State, Nigeria during the 2011-12 and 2012-13 dry seasons. The major sources of the irrigation water are from the Benue River, Geriyo Lake and tube wells, while rice is the major crop grown in the area followed by other vegetables (EPLAN, 2004). The area is underlain by the Bima sandstone and recent river alluvium (Ishaku, 2011). The area is characterized by an average annual rainfall of between 900– 1000mm. 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 (Adebayo and Nwagboso, 2005).

Table 1. Initial Physical Properties of the Soil 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})	0.44
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 experiment was arranged in a split plot design with three replications in which irrigation regimes were main factor included: 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, I_4 =Withholding irrigation at the vegetative stage for 14 days, I_5 = Withholding irrigation at the reproductive stage for 14 days, I_6 =Withholding irrigation at the ripening stage for 14 days and nitrogen fertilizer levels were the sub factor included0, 50, 100 and 150kg N ha^{-1}. The area of each experimental plot was 4 x 3m.

A uniform irrigation frequency based on the consumptive use of the crop was employed for all the treatments from transplanting to full establishment. Surface irrigation method was used in conveying water into each basin. The canals were lined with polyethene sheet to reduce the rate of seepage and allow free flow. 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 Trimmer (1994) formula: 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). Rice variety FARO 44 seedlings were transplanted to the field 30 days after sowing at the rate of two seedlings per hill with a spacing of 20cm x 20cm.Basal application of Phosphorus and Potassium fertilizers was applied to all plots and worked well into the soil one week before transplanting at the rate of 60kg P_2O_5 and 60kg K_2O per hectare using Single Super Phosphate Fertilizer (SSP) and Muriate of Potash respectively as recommended by WARDA, (2008) under low soil fertility class. The Nitrogen fertilizer was applied by broadcasting to the plots according to the nitrogen treatment, using Urea fertilizer in three equal doses, one-third at transplanting, one-third at mid-tillering and the other one-third at panicle initiation. At maturity a 1m x 1m sub area from the center of each plot was harvested with the aid of sickle by cutting the above ground dry matter and weighed. The harvested rice was then threshed and weighed to obtain grain weight. The grain moisture content at threshing was determined in the laboratory to be 13.2%. Nitrogen Uptake was calculated on the basis of nitrogen concentration measured in grain or straw multiply by the grain yield in kg ha^{-1} and then divided by 100 (Ryan *et al.,* 2001).

RESULTS

The relation between nitrogen levels (kg ha^{-1}) and grain yield combined for both years of study showed significant and positive linear relationship between grain yield and nitrogen levels (Fig. 1) with a high (0.946) coefficient of determination (R^2).

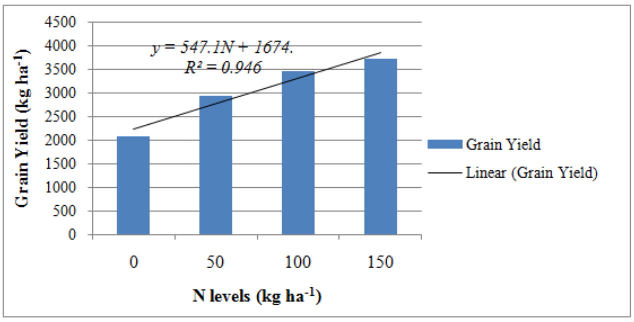

Figure 1: Relationship between nitrogen levels and rice grain yield. (The 2 years combined data)

The mean grain yield, N concentration in grain and straw and N uptake of rice grain have significantly (*P < 0.05*) responded to irrigation regimes and nitrogen fertility levels in both seasons (Table 2). The maximum nitrogen content (14.3 and 15.4 g kg^{-1}) in grain was recorded with 4 days irrigation interval (I_1), statistically at par with 8 days irrigation interval (I_2) and irrigation with holding at ripening stage (I_6). The N content in straw (2.50 and 2.60 g kg^{-1}) was equally higher with 4 days

Table 2. Mean Main Effects of Irrigation Regimes and Nitrogen Rates on Grain Yield (kg ha-1), Nitrogen Concentration in Grain and Straw (g kg-1) and N Uptake in Rice (kg ha-1) during the 2011/2012 and 2012/2013 sessions

Table 2. SON	2011/2012				2012/2013			
Irrigation regimes	Grain Yield	Grain N	Straw N	N Uptake	Grain Yield	Grain N	Straw N	N Uptake
I_1	4283.64	14.30	2.50	64.33	5005.09	15.40	2.60	65.66
I_2	3557.08	14.00	2.40	45.86	3798.86	14.70	2.50	46.81
I_3	1191.26	11.80	2.10	27.37	1364.97	12.20	2.10	27.93
I_4	2817.46	11.80	2.10	41.98	2624.15	12.80	2.20	42.85
I_5	2082.22	12.80	2.30	41.66	2835.03	13.80	2.40	42.53
I_6	3199.34	13.50	2.30	51.93	3702.02	14.20	2.40	53.01
HSD($P\leq0.05$)	840.52	1.00	0.10	10.25	857.35	1.30	0.10	7.76
Nitrogen rates								
N_0	1990.05	7.60	1.40	16.61	2151.00	7.30	1.30	16.95
N_1	2775.13	12.80	2.30	45.82	3088.06	13.80	2.40	46.10
N_2	3296.31	15.40	2.70	55.00	3586.60	16.60	2.80	56.81
N_3	3454.17	16.30	2.80	64.66	3994.43	17.60	3.00	65.99
HSD($P\leq0.05$)	1066.62	0.80	0.10	8.38	1008.48	2.00	0.10	6.32
Interaction								
Irrigation regimes x Nitrogen rates	*	*	*	*	*	*	*	*

Where: N_0= 0kg N ha^{-1}, N_1= 50kg N ha^{-1}, N_2 = 100kg N ha^{-1} and N_3 = 150kg N ha^{-1} , I_1=4 days irrigation interval, I_2= 8 days irrigation interval, I_3= 12 days irrigation interval, I_4= Withholding irrigation at the vegetative stage, I_5 = Withholding irrigation at the reproductive stage and I_6 = Withholding irrigation at the ripening stage, HSD= Turkey Honesty Significant Difference and * significant at 5% probability level

irrigation interval (I_1) in both seasons respectively. The minimum concentrations of nitrogen in grain (11.8 and 12.2 g kg^{-1}) and straw (2.10 and 2.10 g kg^{-1}) were influenced by irrigation regimes were recorded with 12 days irrigation interval (I_3) respectively for the two seasons. The nitrogen fertility level has also significantly ($P < 0.05$) affected the concentrations of N in both grain and straw in the two seasons. Maximum N concentration in grain (16.30 and 17.60 g kg^{-1}) and in straw (2.80 and 3.00 g kg^{-1}) was recorded in 150 kg N ha^{-1}(N_3) treatments in both years respectively.

both seasons as well. The highest N uptake (64.66 and 65.99 kg ha^{-1}) was recorded with 150kg N ha^{-1} (N_3) for both seasons respectively. The minimum N uptake was recorded in 0kg N ha^{-1} (N_0) treatments in both seasons.

Interaction effect of irrigation regimes and nitrogen levels

Figure 2 presented an interaction effect of irrigation regimes and nitrogen fertility levels on nitrogen concentration in grain pooled over 2011/2012 and 2012/2013 seasons.

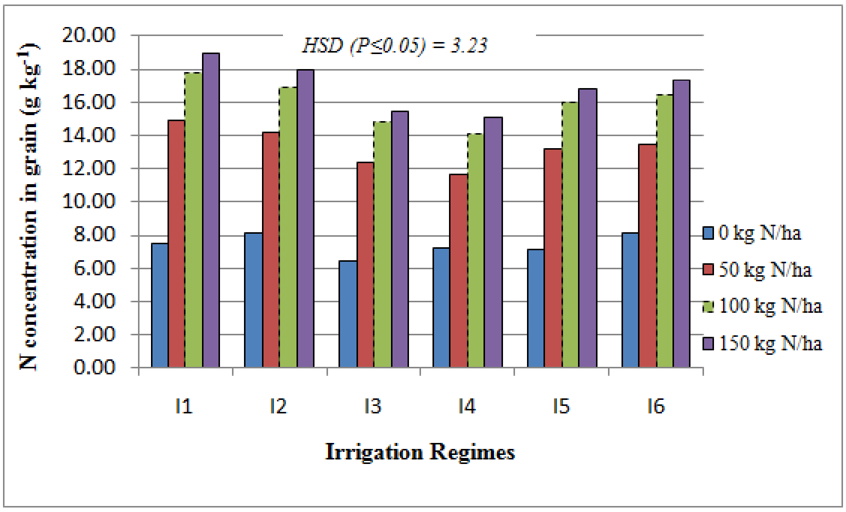

Figure 2. Interaction Effects between Irrigation Regimes and Nitrogen Rates on N Concentration in Grain (g kg^{-1}) Pooled over the Seasons

The minimum N content in grain and straw in the two years were registered with the control treatment (N_0). Significant response to irrigation treatments was observed on N uptake by rice grain in both 2011/2012 and 2012/2013 dry seasons (Table 2). 4 days irrigation interval (I_1) significantly ($p < 0.05$) had higher N (64.33 kg ha^{-1}) uptake in 2011/2012 and (65.66 kg ha^{-1}) in 2012/2013 season. The least was recorded with 12 days irrigation interval (I_3) with the following values 27.37 kg ha^{-1} in 2011/2012 and 27.93 kg ha^{-1} in 2012/2013 season. Nitrogen fertility level also affected N uptake significantly in

The highest nitrogen contents in grain (18.95 g kg^{-1}) as recorded with the 4 days irrigation interval and 150 kg N ha^{-1} (I_1N_3) treatment, but was statistically ($P < 0.05$) at par with 4 days irrigation interval with 100 kg N ha^{-1} (I_1N_2) treatment, 8 days irrigation interval with 150 and 100 kg N ha^{-1} (I_2N_3 and I_2N_2) treatments and irrigation with holding at ripening stages with 150 and 100 kg N ha^{-1} (I_6N_3 and I_6N_2) treatments. Highest N content in straw (3.20 g kg^{-1}) of the rice plant pooled over the two years (Figure2), were recorded under the interaction of 4 days irrigation interval with 150 kg N ha^{-1} nitrogen fertility level (I_1N_3) treatment, statistically not different to 4 days irrigation interval with 100 kg N ha^{-1} (I_1N_2) treatment, 8 days irrigation interval with 150 and 100 kg N ha^{-1} (I_2N_3 and I_2N_2) treatments and irrigation with holding at ripening stages with 150kg N ha^{-1} (I_6N_3) treatments. The lowest nitrogen content in grain (6.45 g kg^{-1}) and straw (1.25 g kg^{-1}) was registered in I_3N_0 pooled over the two seasons (figures 2 and 3).

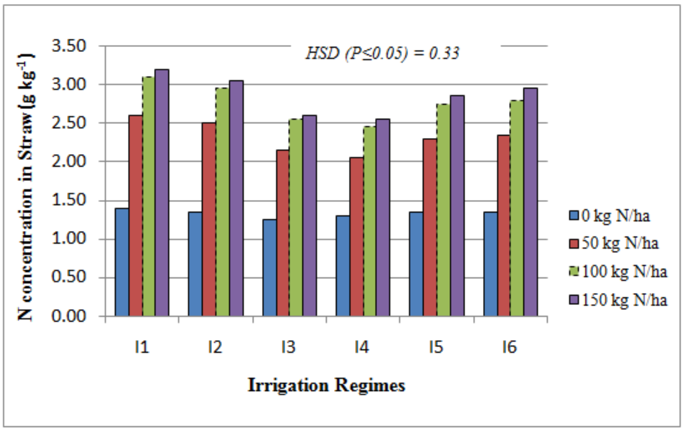

Figure 3. Interaction Effects between Irrigation Regimes and Nitrogen Rates on N Concentration in Straw (g kg^{-1}) Pooled over the Seasons

The results of the interaction effect between irrigation regimes and nitrogen fertility levels on the uptake of nitrogen by the rice grain in both 2011/2012 and 2012/2013 dry seasons pooled over was presented in Figure 4. The highest N uptake (91.17 kg ha^{-1}) was observed with the combination of 4 days irrigation interval regime with 150kg N ha^{-1} nitrogen fertility level (I_1N_3) treatments, statistically at par with 4 days irrigation interval with 100kg N ha^{-1} nitrogen fertility level (I_1N_2) treatments and irrigation with holding at ripening stage regime with 150kg N ha^{-1} nitrogen fertility level (I_6N_3) treatments. The lowest N uptake (10.81kg ha^{-1}) was recorded with the 12days irrigation interval regime and 0kg N ha^{-1} nitrogen fertility level (I_3N_0) treatment.

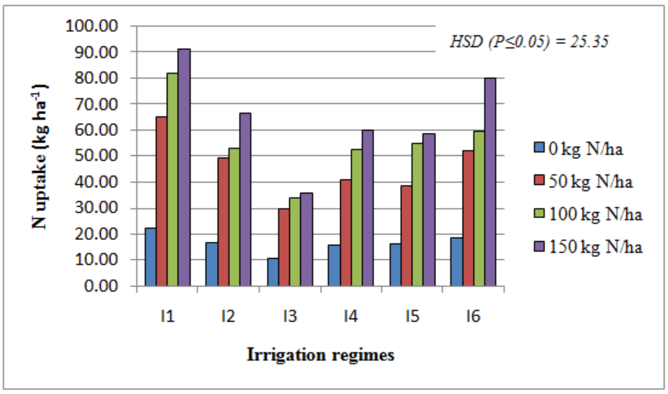

Figure 4. Interaction Effects between Irrigation Regimes and Nitrogen Rateson Nitrogen Uptake of Rice Grain (kg ha^{-1}) Pooled over the Seasons

DISCUSSION

The relationship between rice grain yield and nitrogen rate was found to be linear, implying that increase in rice yield is expected at a particular rate as the N-rate increases (Fig. 1). The equation $y = 547.1N + 1674,\ R^2 = 0.946$revealed that rice grain yield increases by 547.1 kg ha^{-1} per every unit increase in the rate of nitrogen fertilizer and has accounted for over 90% of the variation in grain yield. The results indicated that the treatments had significant influenced on N concentration both in grain and straw of the rice crop. The N concentration of grain varied with irrigation regimes with I_1 producing higher N content, but statistically not different with I_2 andI_6. This result is in agreement with the findings of Pradeep *et al.* (1994) who observed high nitrogen concentration of rice grain with 3 days irrigation interval, but statistically at par with 6 and 9 days interval. Similar findings have also been reported by Chowdhary *et al.* (2014) who noted that greater amount of nutrient rice grain at higher level of irrigation was due to more conductive for uptake of nutrients by plants. The N content in grain and straw reveal positive response to N fertilizer treatments as well. The average maximum (16.95 g kg^{-1}) and minimum (7.45 g kg^{-1}) nitrogen concentration in grain and straw were obtained with the highest and lowest levels of N application. Chaturvedi (2005) reported an average value of 14.5 g kg^{-1} N content in rice grain with the application of 100 kg N ha^{-1} using urea fertilizer, which was below the average 16.00 g kg^{-1} N content in grain obtained from this experiment. The N concentration in grain for N treatments 50 to 150kg N ha^{-1} were within the range of 12.8 g kg^{-1} reported by Cassman *et al.* (1997) to be desired in the grain of rice for optimal cooking and eating quality. Pirmoradian *et al.* (2004) reported similar finding that increasing N application resulted in increasing grain and straw nitrogen concentration. The result showed that N concentration in grain was higher than that obtained in straw. This was confirmed by Kiniry *et al.* (2001) who reported that the nitrogen concentration in grain was always higher than the stover. However, Fageria *et al.* (2010) reported that N concentration in grain was not influenced by N treatments.

The interaction effects between irrigation and nitrogen treatments on grain and straw N concentration were statistically significant in both years. Maximum N concentration was obtained from I_1N_3, not significantly different from I_2N_3, I_6N_3 and I_1N_2. Minimum N concentration in grain and straw was obtained from 12 days irrigation interval with no N application. These results were in accordance with Pirmoradian *et al.* (2004) who reported higher N concentration in grain and straw of rice plant in treatments having higher levels of N application and the minimum with no N application treatments with little variation in irrigation levels. Nitrogen uptake in grain had a significant response to irrigation regimes and N fertilization level. Maximum grain N uptake was obtained with 4 days irrigation interval, while the minimum was with 12 days irrigation interval in both seasons. N uptake decreased with decreases in irrigation frequency and growth stages, the maximum was reached with irrigation withholding at ripening stage (I_6) and lowest under irrigation withholding at reproductive stage (I_5). N uptake was in the following decreasing order: $I_1 > I_6 > I_2 > I_4 > I_5 > I_3$. Similar observations were made by Kumar and Pannu (2012) who reported N uptake of wheat to increase with increased levels of irrigation. Similar trend for rice N uptake was reported by Pirmoradian *et al.* (2004). It is also in agreement with the findings of Chowdhary *et al.* (2014) who reported that uptake of N was found to be at maximum in the treatment which received the maximum number of irrigation and noted that greater amount of N uptake by rice at higher level of irrigation was because of more conductive for uptake of nutrients by the plants. In response to N fertility level, highest N uptake was obtained in 150kg N ha^{-1} and minimum in control treatment. This is in agreement with the findings Yu *et al.* (2013) and Al-Gusaibi (2004) which showed an increasing trend in uptake of nitrogen by the rice plants from 0kg N ha^{-1} to 150kg N ha^{-1}. Similar results were reported on N uptake increasing with the increase in N application level by Tayefe *et al.* (2011), Khan and Imtiaz (2013), Al-Gusaibi (2004) and Fageria *et al* (2003) who associated it with the dry matter production and grain yield.

Conclusion

The study indicated that irrigation interval of between 4 to 8 days and irrigation withholding at ripening stage with the application of 100 to 150 kg N ha^{-1} cannot only save irrigation water and reduce cost of production but may improve the N uptake of lowland rice production on clay loam soils of Adamawa State of Nigeria. Since lower N uptake was recorded in low N fertilizer rate, integrated nutrient and soil fertility management which combines organic and inorganic fertilizer, mulching, cover cropping, intercropping and low till practices will save the amount of fertilizer applied and improve fertilizer use efficiency. Nitrogen supply should be synchronized with plant demand for nitrogen to maximize plant uptake and minimize loss.

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