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# EFFECT OF NITROGEN RATE ON YIELD AND NITROGEN USE EFFICIENCY OF SOME RICE (*Oryza sativa* L.) VARIETIES UNDER IRRIGATED CONDITION IN GASHUA,YOBE STATE, NIGERIA

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## ABSTRACT

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*This study was conducted to evaluate the effect of different nitrogen rates on yield, agronomical efficiency, partial factor productivity of applied N and grain harvest index on five varieties of rice. The experiment was conducted in two locations in Gashua, Yobe State, Nigeria during the 2016/ 2017 dry season under irrigated conditions. The results obtained revealed that application of 45kg Nha$^{-1}$ gave the highest agronomic efficiency, partial factor productivity of applied N and grain harvest index, while application of 135kgNha$^{-1}$ gave the highest grain yield. The application of 180kg Nha$^{-1}$ gave the highest biological yield, FARO 61 had the highest grain yield, biological yield, and partial factor of productivity of applied N and grain harvest index, FARO 60 had the highest agronomical efficiency. FARO 44 had the lowest value for all the parameters measured. The value obtained in FARO 44 was lower than that obtained in the local variety. All the variety evaluated except FARO 44 performed better than the local variety. Farmers are therefore advised to grow FARO 52, FARO 60, FARO 61 and the local variety JAMILA under irrigation during the dry seasons witha basal application of 50 kg $P_20_5$ ha$^{-1}$ and 40 kg $K_2O$ during land preparation and 135kg Nha$^{-1}$ split into two halves (at two weeks and at six weeek after transplanting), in order to promote yield of rice in Gashua.*

**Keywords**: *Yield, nitrogen use efficiency, rice varieties, irrigation, Gashua*

## INTRODUCTION

Rice (Oryza sativa L.) is the main food crop of an estimated 40% of the world's population (Osiname, 2004) and the demand for rice is rapidly increasing in West Africa. The World's more than three billion people depend on rice as their staple food (FAO, 2009). Local production, especially in Africa and particular in Nigeria, is low (averaging about 2.5 t ha$^{-1}$). Efforts to increase production are hindered by high input costs and low yields, especially under rain-fed conditions and erratic climate variability. Demand for rice has been on the increase in sub-Sahara Africa. Between 1985 and 2001 rice imports to Africa was more than doubled, rising from 3 million to 7.5 million tons per annum (FAO, 2009) and Nigeria spends over three hundred and fifty-six billion naira (N356 billion) on the yearly importation of rice. It is rapidly becoming the staple food in other countries of West Africa, hence becoming an important crop in the context of food security. As there are many people in the major rice consuming countries living at sub-optimal nutritional levels, there is a need to increase rice production by as much as 70% to raise nutrient levels to satisfy current dietary needs (Osiname, 2004).

In sustainable agricultural practices, nutrient management practices include both crop and soil fertilization. Crop fertilization refers to fertilizer application according to the crop demands, while soil fertilization is targeted to replenish its fertility level. The strategy of efficient fertilizer management program involves a correct decision on the right rate, source, time, and place of fertilizer application (Bruulsema *et al*., 2009). The amount of fertilizers to be applied for a target yield may be determined by soil testing, nutrient response or missing element trial techniques. As noted by Oikeh *et al*., (2009), nutrient deficiency in rice is a major constraint to rice production not only in Gashua but throughout the West Africa. Further increase in rice production has to be achieved with less N fertilizer by improving N use efficiency (NUE) through better N fertilizer management and new rice varieties. Research on improving NUE of the rice crop has been focused on the development of fertilizer management strategies in the past three decades, and considerable progress has been achieved to reduce N losses by new application methods and modified N sources. Another important research area is optimizing the timing and rate of N application for better synchronization between the supply and demand of N by the crop (Cassman *et al*., 1998).

Nitrogen deficiency is related to low N use efficiency by the crop due to loss by leaching, volatilization, di-nitrification and erosion as reported by (Fageria and Baligar, 2005). Nitrogen use efficiency is usually low and N recovery may even get lower under certain management conditions (Dobermann *et al*., 2004). Loss of N to the environment usually takes place when high concentrations of soluble N forms are present in the soil solution in excess compared to the amount that plants can take up (Fageria and Baligar, 2005). These losses could be reduced with good management practices such as application rate commensurable with the crop needs, placing the fertilizer where the plants can easily reach the nutrients, and choosing the right application time. Rice varieties differ significantly in N uptake and utilization efficiency (Fageria, 2007), and it is known that the response of crops to nitrogen varies is due to their genetic makeup.

Also, one of the major constraints to rice production in dry lands is the inabilty of the farmers to adopt high yielding varieties which are medium to late – matuing. The widely grown local varieties in the study area are early -maturing, which are usually associated with low yield. Hence, the use of high yielding improved varieties, which cannot be grown under rainfall condition in the study area in conjunction with the use of chemical fertilizers under irrigated condtion may be a complementary strategy in improving rice yield. It, therefore, becomes imperative to investigate the response of some of the these improved rice varieties to different rates of N- fertilizer under irrigation. The specific objectives of this study is to evaluate yield response, agronomic efficiency, partial factor productivity of applied N and grain harvest index of rice at Gashua in the Sahelian agro-ecological zone with a view to developing alternative fertilizer recommendation (AFR) for the rice varieties being evaluated.

## MATERIALS AND METHODS

The experiment was conducted in location I (12.8765° N, 11. 0316° E at approximately 299 M above sea level ) and location II (12.8740° N 11.0406° E at approximately 299 M above sea level) in Gashua, Yobe State, Nigeria during the 2016/ 2017 dry season under irrigated conditions. The soil samples was collected using auger at (0 – 30cm) depth. The samples collected was bulked to obtain a composite (20 cores for each of the three replicates), air-dried, crushed, screened through a 2mm sieve and taken to Soil Science Department of Ahmadu Bello University Laboratory for soil physical and chemical analysis and the result was presented as Table 1. The experiment was laid down as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times. Factor one was the rice varieties (FARO 44, FARO 52, FARO 60, FARO 61, and a local variety called JAMILA) while factor two consists of the different rates of nitrogen applications comprisig non application (check), 45 kg N $ha^{-1}$ , 90 kg N $ha^{-1}$, 135kg N $ha^{-1}$ and 180kg N $ha^{-1}$. The N was split into two halves (at two weeks and at six weeks after transplanting). Each replication consists of 25 treatment combinations (plots). There were 75 plots in each location. The land was ploughed and harrowed before planting. After land preparation, the field was divided into basins of 3 m by 3 m (9 $m^2$) each. The blocks was separated by an alley of 1 m, and the plots was demarcated with high bunds of 20 cm so as to minimize lateral movement of fertilizer (nitrogen) from one plot to another, in addition to the conservation of water within the plot. The nurseries was raised by planting each rice variety (35 kg $ha^{-1}$) on a 4 m x 4 m plot using drilling method. Each plot was regularly watered to maintain optimum moisture using furrow method of irrigation. Rice seedlings raised from the nurseries were transplanted at 2 seedlings per hill at a spacing of 0.2 × 0.2 m to give a total population of 500, 000 plants $ha^{-1}$. Each plot received a basal application of 50 kg $P_20_5$ $ha^{-1}$ and 40 kg $K_2O$ during land preparation. These fertilizer rates were based on the recommendations of Aduayi *et al*. (2002). Pre-emergent herbicide (Pendimethalin), was applied at the rate of 4 $lha^{-1}$ one day before transplanting and post-emergent herbicide Orizo plus (360g Propanil + 200g 2,4-D ) at the rate of 10 liters $ha^{-1}$ was applied at three week after transplanting. Subsequently, weeds was controlled by hand pulling as at when necessary. Harvest was made at maturity (when the entire plants have turned golden brown, and the panicle has dried). The fresh and dry weight of all harvested plant parts was determined. At physiological maturity, all plants in the plot were harvested to determine grain yield and yield components. The remaining portion of the field was harvested, threshed, and combined with grain from the 2.0 x2.0 $m^2$ quadrant to estimate grain yield at 14% moisture content. Harvested plant samples (straw and grain) were shredded, sub-sampled, and oven-dried at 65 °C to a constant weight to determine biological yield. The result obtained was used to calculate the following yield efficiencies and harvest indices (Fageria *et al*., 2010).

Agronomic efficiency (ANE) = $(Gf - Gu / Na) = kg\ kg^{-1}$

Where: Gf is the grain yield of the fertilized plot (kg),
Gu is the grain yield of the unfertilized plot (kg), and
Na is the quantity of N applied (kg).

Partial factor productivity of applied N (PFPN) $= \frac{\text{GYN}}{\text{FN}} = \frac{kg\ grain\ yield}{kg\ N\ applied}$

Where: GYN is the grain yield in treatment with N application (kg $ha^{-1}$)
FN is the unit of fertilizer N applied (kg $ha^{-1}$)

Grain harvest index GHI= $\frac{\text{Grain yield}}{\text{Grain and shoot yield}}$.

Data collected was subjected to analysis of variance (ANOVA) using the mixed model procedure of SAS (Littell *et al*., 1996). Differences between treatments means was compared using Duncan Multiple Range Test (DMRT) at 5% level of probability.

## RESULTS AND DISCUSSION

As shown in Table 1 the soil in the study areas was sandy loam, very low in organic carbon and nitrogen, moderate in available phosphorus and high in excchangeable potassium. Location I was strongly acidic while location II is neutral in reaction (FMARD, 2011).

Table 1: Properties of the soil of the experimental sites in 2016/2017 dry seasons at Gashua

| | Locations | |
|---|---|---|
| Soil Parameters | Location I | Location II |
| Particle size distribution (g $kg^{-1}$) | | |
| Clay | 16 | 12 |
| Silt | 28 | 34 |
| Sand | 56 | 54 |
| Textural class | sandy loam | sandy loam |
| Chemical properties | | |
| pH in water 1: 2.5 | 5.28 | 6.83 |
| pH in $Cacl_2$ 1: 2.5 | 4.78 | 5.99 |
| ECE ($dsm^{-1}$) | 0.014 | 0.05 |
| Organic Carbon (g $kg^{-1}$) | 1.344 | 0.58 |
| Total N (g $kg^{-1}$) | 0.21 | 0.35 |
| Available P (mg $kg^{-1}$) | 9.81 | 13.95 |
| Exchangeable Cation | | |
| K (cmol $kg^{-1}$) | 1.71 | 0.73 |
| Mg (cmol $kg^{-1}$) | 0.92 | 0.92 |
| Ca (cmol $kg^{-1}$) | 8.85 | 7.70 |
| Na (cmol $kg^{-1}$) | 0.87 | 0.77 |
| H + Al (cmol $kg^{-1}$) | 1.2 | 0.8 |
| ECEC (cmol $kg^{-1}$) | 13.55 | 10.92 |

There was a significant increase in the yield of rice grain with an increase in N rate up to 135 kg N $ha^{-1}$ but there was a significant decrease in grain yield at higher rates of 180 kg $Nha^{-1}$. There was significant increase in straw and biological yield as the rate of N was increased from 45 kg N $ha^{-1}$ up to 180kg $Nha^{-1}$. The significant increases in rice grain yield could be attributed to the fact that the applied N is essential for plant growth and development. It has been reported that nitrogen helps in photosynthetic activities, vigorous growth and plant development. Application of N beyond 135 kg $Nha^{-1}$ resulted in more vegetative growth and decreased grain yield, this is because excessive N application usually resulted in more vegetative growth at the expense of grain yield. The poor performances in plots that did not receive N compared to where it was applied could be due to very low fertility status of the study area thereby resulting to low yield in the check. FARO 61 gave the highest rice grain yield and biological yield, which was followed by FARO 60 and then FARO 52. However, FARO 44 gave the lowest yield. The local variety used performed better than FARO 44 with respect to rice grain yield. FARO 52 gave the highest straw yield while FARO 44 gave the lowest straw yield. There were similarities in term of straw yield between FARO 61 and the local varieties and also between FARO 61 and FARO 60 respectively as shown in Table 2. All the varieties evaluated in this experiment were essentially adapted to lowland / irrigated swamp and they exhibited consistent significant differences in yield and the other variable measured. These differences could be attributed to variations in their genetic makeup and gene interaction with environment. This difference has some effects on how efficiently water and nutrients can be utilized by the crop for production.

The agronomical efficiency and partial factor productivity of applied N significantly decreased with increasing N rate applied. Application of 45kg$Nha^{-1}$ had the highest, which was followed by 90kgN, then 135kg $Nha^{-1}$ while the application of 180 kg $Nha^{-1}$ had the lowest agronomical efficiency and partial factor productivity of applied N. Similarly, application of 45 kg $Nha^{-1}$ gave the highest significant grain harvest index in both locations, which was followed by application of 90 kg $Nha^{-1}$, beyond the application of 90 kg $Nha^{-1}$ a significant decrease in partial factor productivity of applied N was observed in both locations and the decrease in the partial factor productivity of applied N decrease with increasing N rates (Table 3).

Similarly as shown in Table 3, FARO 60 had the highest significant agronomicFARO 60 had the highest significant agronomical efficiency in both locations. The agronomical efficiency of the local variety was significantly higher than that of FARO 44. FARO 61 had the highest significant partial factor productivity of applied N in both locations, which was followed by FARO 60. In location 1 the partial factor productivity of applied N for FARO 44, FARO 52 and the local variety were same, while in location 2 FARO 44 had the lowest partial factor productivity of applied N. FARO 61 had the highest significant grain harvest index which was followed by FARO 60, FARO 52 and then the local variety, while FARO 44 had the lowest value for grain harvest indexal efficiency in both locations. The agronomical efficiency of the local variety was significantly higher than that of FARO 44. FARO 61 had the highest significant partial factor productivity of applied N in both locations, which was followed by FARO 60. In location 1 the partial factor productivity of applied N for FARO 44, FARO 52 and the local variety were same, while in location 2 FARO 44 had the lowest partial factor productivity of applied N. FARO 61 had the highest significant grain harvest index which was followed by FARO 60, FARO 52 and then the local variety, while FARO 44 had the lowest value for grain harvest index (Table 3).

Table 2: Grain yield, straw yield and biological yield of rice at Gashua during the 2016/2017 dry season

| Treatments | location I grain yield | location II grain yield | mean grain yield | location I straw yield | location II straw yield | mean straw yield | location I biological yield | location II biological yield | mean biological yield |
|---|---|---|---|---|---|---|---|---|---|
| Nitrogen (kg per ha) | | | | | | | | | |
| 0 | 1961e | 1326e | 1643e | 216e | 288e | 252e | 2176e | 1614e | 1895e |
| 45 | 3939d | 3304d | 3621d | 279d | 351d | 315d | 4218d | 3656d | 3937d |
| 90 | 4031c | 3396c | 3713c | 506c | 578c | 542c | 4537c | 3974c | 4255c |
| 135 | 4207a | 3572a | 3889a | 791b | 864b | 827b | 4910b | 4348b | 4629b |
| 180 | 4119b | 3484b | 3801b | 872a | 945a | 908a | 5079a | 4517a | 4797a |
| SE± | 0.0002 | 0.0002 | 0.0276 | 6.4367 | 6.43 | 4.451 | 6.43 | 6.43 | 6.269 |
| Varieties | | | | | | | | | |
| Faro 44 | 3372e | 2737e | 3054e | 494d | 567d | 530d | 3866e | 3303e | 3585e |
| Faro 52 | 3418c | 2783c | 3100c | 592a | 665a | 629a | 4011c | 3449c | 3730c |
| Faro 61 | 4136a | 3501a | 3818a | 525bc | 598bc | 562bc | 4661a | 4099a | 4380a |
| Faro 60 | 3937b | 3302b | 3619b | 509cd | 582cd | 545cd | 4446b | 3884b | 4165b |
| local | 3395d | 2760d | 3077d | 543b | 616b | 580b | 3938d | 3376d | 3657d |
| SE± | 0.0002 | 0.0002 | 0.0276 | 6.4367 | 6.43 | 4.451 | 6.43 | 6.43 | 6.269 |
| interactions | | | | | | | | | |
| N* V | NS | NS | NS | NS | NS | NS | NS | NS | NS |

Means within a column of treatment followed by unlike letter(s) are significantly different at 5% percent level of significant

Table 3: Agronomic efficiency, partial factor productivity of applied N and grain harvest index of rice at Gashua during the 2016/2017 dry season

| Treatments | location I ANE | location II ANE | mean ANE | location I PFPN | location II PFPN | mean PFPN | location I GHI | location II GHI | mean GHI |
|---|---|---|---|---|---|---|---|---|---|
| Nitrogen (kg per ha) | | | | | | | | | |
| 0 | 0e | 0 | 0e | 4e | 0e | 2.00e | 0.888c | 0.821c | 0.861c |
| 45 | 44a | 43.97a | 43.97a | 88a | 73a | 80a | 0.933a | 0.903a | 0.918a |
| 90 | 23b | 23.00b | 23.00b | 45b | 38b | 41b | 0.901b | 0.853b | 0.870b |
| 135 | 16c | 15.99c | 15.99c | 31c | 26c | 28c | 0.838d | 0.799d | 0.816d |
| 180 | 12d | 12.48d | 12.48d | 23d | 20d | 21d | 0.827e | 0.789e | 0.808e |
| SE± | 0.0002 | 0.0002 | 0.0002 | 0.2315 | 0.0661 | 0.0728 | 0.0075 | 0.0008 | 0.0008 |
| Varieties | | | | | | | | | |
| Faro 44 | 15.49e | 15.49e | 15.49e | 35c | 28e | 31d | 0.860e | 0.813e | 0.836e |
| Faro 52 | 15.52c | 15.52c | 15.52c | 35c | 29c | 32c | 0.878c | 0.832c | 0.855c |
| Faro 60 | 24.91a | 24.91a | 24.91a | 42b | 35b | 38b | 0.889b | 0.845b | 0.867b |
| Faro 61 | 24.01b | 24.01b | 24.01b | 44a | 37a | 40a | 0.891a | 0.853a | 0.872a |
| Local | 15.51d | 15.51d | 15.51d | 35c | 28d | 32cd | 0.869d | 0.822d | 0.845d |
| SE± | 0.0002 | 0.0002 | 0.0002 | 0.2315 | 0.0661 | 0.0728 | 0.0075 | 0.0008 | 0.0008 |
| interactions N* V | NS | NS | NS | NS | NS | NS | NS | NS | NS |

Means within a column of treatment followed by unlike letter(s) are significantly different at 5% percent level of significant

Higher significant values were obtained in all the parameters measured in location 1 when compared to that measured in location 2 except the agronomical efficiency which is same for both locations (Table 4) this may not be unconnected to the relatively higher values for soil fertility recorded in location 1.

Table 4: Effect of location on yield and yield attribute of rice in Gashua yield and yield parameters

| locations | Grain yield | Straw yield | Biological yield | ANE | PFPN | GHI |
|---|---|---|---|---|---|---|
| L1 | 3651a | 606a | 4184a | 19.09 | 37.99a | 0.877a |
| L2 | 3016b | 533b | 3622b | 19.09 | 31.36b | 0.832b |
| SE± | 3.909 | 6.296 | 8.868 | 0.0001 | 0.103 | 1.41555 |

Means within a column of treatment followed by unlike letter(s) are significantly different at 5% percent level of significant

Low N use efficiency by the crop may be due to loss by leaching, volatilization, di-nitrification and erosion as reported by (Fageria and Baligar, 2005). Nitrogen use efficiency is usually low and N recovery may even get lower under certain management conditions (Dobermann et al., 2004). The method of application (broadcasting) may have also contributed to N loss. Loss of N to the environment usually takes place when high concentrations of soluble N forms are present in the soil solution in excess compared to the amount that plants can take up

(Fageria and Baligar, 2005). The rice varieties differ significantly in N uptake and utilization efficiency and it is known that the response of crops to nitrogen varies due to the genetic makeup of the crop.

## CONCLUSION

The application of 45kg Nha$^{-1}$ gave the highest agronomic efficiency, partial factor productivity of applied N and grain harvest index. Application of 135kgNha$^{-1}$ gave the highest grain yield while the application of 180kg Nha$^{-1}$ gave the highest biological yield. FARO 61 had the highest grain yield, biological yield,partial factor productivity of applied N and grain harvest index while FARO 60 had the highest agronomical efficiency. FARO 44 had the lowest value for all the parameters measured.The value obtained in FARO 44 was significantly lower than that obtained in the local variety. All the varieties evaluated except FARO 44 performed better than the local variety. Farmers are therefore advised to grow FARO 52, FARO 60, FARO 61 and the local variety JAMILA under irrigation during the dry seasons witha basal application of 50 kg $P_20_5$ ha$^{-1}$ and 40 kg $K_2O$ during land preparation and 135kg Nha$^{-1}$ split into two halves (at two weeks and at six weeek after transplanting), in order to promote yield of rice in Gashua.

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