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Lowland Rice (*Oryza sativa* L*)* Yield Response to Nutrients Application in Kadawa and Wushishi, Nigeria

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ABSTRACT

Rice is a staple food crop for over 50% of the world's population. In Nigeria, rice is becoming more important crop to smallholder farmers and constitute to 8.69% of household food expenditure and 4.92% of total household expenditure. On-farm NPK fertilizer-response trials were conducted in 2015 at Kadawa and Wushishi in Kano and Niger States, respectively under the auspices of OFRA Project. The aim was to determine paddy yield responses to NPK fertilizer. The treatments consisted of 20 fertilizer rates of partial factorial combinations laid out on a randomized complete block design, replicated 3 times, in each location. Results showed that, highest paddy yield of 4.43 tons ha^{-1}was achieved when NPK was applied at the rate of 80N.15P.0K (kg ha^{-1}) in Wushishi. At Kadawa, the highest yield of 4.04 tons ha^{-1} was achieved when NPK was applied at the rate of N 120 and P 15. Response of yield to K was not significant in the two locations, indicating the soils capacity to supply the nutrient (K) from indigenous sources. Yield response to Zinc at Kadawa shows that the soils are being depleted of micronutrient. It was concluded that N was the most limiting nutrient in the two locations with Kadawa being prominent. Micronutrients in soils of Kadawa are being mined and with time there is need for replenishment for a meaningful yield attainment. It was recommended that fertilizer recommendations should tailor the use of N at 80 and 120 kg N ha^{-1} at Wushishi and Kadawa, respectively.

Key words: Lowland rice, Nutrients, yield response, nutrients, nitrogen, phosphorus, potassium

Introduction

Rice (*Oryza satva* L.) is both an important cash and food security crop in sub-Saharan Africa (SSA). In Nigeria, Sudan and Guinea savannahs account for about 60% of the national rice production. However, average grain yield of rice on farmers' fields is low (2.5 t/ha) compared with the achievable yield of 5-6 t/ha, due to low soil fertility, and sub-optimal application of fertilizers (MoFA, 2010).Increasing pressure on land due to increasing population and competing uses of land have shortened fallow periods leading to continuous cropping and consequently undesirable effects on soil structure and mineral status (Oikeh *et al*., 2009) Due to continuous cropping and low plant-available soil nitrogen (N) and phosphorus (P), external nutrient additions in the form of fertilizers have become inevitable to achieve higher yields.

The global demand for rice is expected to grow for many years largely because of the continuous population growth. To meet the food demands, the yield of rice needs to be increased particularly in rain-fed lowlands and irrigated rice ecosystems, as the scope for increasing rice-growing area in the upland is limited due to urbanization and industrialization. The nutrient requirements of a rice crop can vary from field to field, depending on the crop variety, climate; and crop and soil management. The rice cultivators presume that the nutrient needs of the crop are constant for years and over large areas, with fixed rates of N, P, and K. Additionally, fertilizer recommendations in West Africa are mostly based on a limited number of trials and sites at research stations (IFDC, 2013). The cropping histories at research stations are often very different from farmers' fields. Currently, the blanket fertilizer recommendation of 80-40-30 kg/ha as N, P_2O_5 and K_2O for lowland rice in Nigeria is more than two decades old and this has probably become inadequate, considering the level of decline in soil fertility within the region.

Given the importance of fertilizers for rice production, there is a need to determine the appropriate fertilizer requirements for lowland rice in the Savannah agro-ecological zones of Nigeria. Several studies have shown that application of fertilizer, especially N to rice increased tiller number, plant height, panicle number, leaf size, spikelet number, and grain yield (Oikeh *et al*., 2009). However, there is little or no information on the fertilizer N, P and K requirements of lowland rice varieties in the savannahs of Nigeria. Hence this study will develop reliable updated nutrient management options for rice in the Guinea and Sudan savannah agro-ecological systems of Nigeria.

MATERIALS AND METHODS

Study area

The experiment was conducted at two locations. The first site was the Irrigation Research Station (IRS) of the Institute forAgricultural Research (IAR) located at Kadawa which is situated on latitude 11^{0} 39′ N, Longitude 08^{0} 27′ E and 500m above sea level in the Sudan agro-ecological zone of Nigeria. Lowland rice is commonly grown by farmers in the location during the rainy season and augmented by irrigation. The soils of the area overlay older granites and younger metasediments of Precambrian to lower palaeozoic (McCury, 1976)**.** The second site was the Upper Niger River Basin Authority (UNRBA) Irrigation site at Wushishi, Niger State. It is located in the southern Guinea savannah ecological zone on latitude 09^{0} 39′ N and longitude 06^{0} 5′E at an altitude of 104m above sea level. It is located within the flood plains of river Ubandawaki and Bankogi. The mean annual rainfall is about 1000-2000mm. the soils of the area are generally Inceptisols that belong to the aquaept great group of the USDA soil taxonomy. They are derived from the floodplains of river Ubandawaki and Bankogi formed over the interphase of the Nupe sandstone and basement complex with a flat low-laying topography (Oladipo, 1998).

Physical and chemical soil analyses

Composite soil samples (0–20 cm depth) were made from six subsamples from each site. Samples were air-dried, ground and passed through a 2-mm mesh sieve. Soil texture (particle-size distribution) was determined by hydrometer method (Bouyoucos, 1962). Soil pH was measured in water and 0.01M $CaCl_2$ using soil-solution ratio of 1:2.5 (Hendershot *et al*., 1993). Electrical conductivity was determined using conductivity meter. Organic carbon was determined using the Walkley–Black method as described by Nelson and Sommers (1982). The total nitrogen content of the soil was determined by Micro Kjeldhal procedure (Bremner, 1996). Exchangeable bases were extracted with 1N ammonium acetate at pH 7. Exchangeable acidity was determined by titrimetric method (McLean, 1982). Available P was determined using the Bray-1 method (Bray and Kurtz, 1945). Potassium and Na were measured by flame photometer; Ca and Mg on Atomic Absorption Spectrophotometer. Effective cation exchange capacity was estimated by the summation method of exchangeable acidity and exchangeable bases.

Treatments and Experimental Design

The trials were conducted during 2015 wet season at both locations (Kadawa and Wushishi). The experiment was setup in a randomized complete block design. The variety tested was FARO 52, and is irrigated swamp with characteristics of125 – 130 days to maturity and resistance to water lodging. The variety was obtained from Seed Company. The fertilizer nutrient rates evaluated were as follows: 40, 80, 120 and 160 kg N/ha, 7.5, 15 and 22.5 P_2O_5 kg /ha; 10, 20 and 30 K_2O kg/ha. The 15 NPK treatments combinations was an incomplete factorial arrangement with consideration of Liebig's law of the minimum. The site was harrowed with tractor at Kadawa and ploughed with hoe in Kadawa. A nursery bed was prepared adjacent to the experimental field. Bunds were raised around each plot to prevent nutrient drift. The rice was grown in a nursery and transplanted to the main field three weeks after sowing with a spacing of 20cm x 20cm at two seedlings per stand. The field was maintained with 5cm of water. Regular hand pulling was also done. The field was laid out in three blocks consisting of fifteen (15) plots for each block.

Each plot had a dimension of 5m x 3m and 1m between plots. The N, P and K sources were urea, triple super phosphate (TSP) and muriate of potash (MOP). The 25% of N was broadcast after transplanting. At active tillering, 25% N was top dressed; and 50% N was broadcast at panicle initiation. The P and K were applied basally during land preparation before transplanting. Harvesting was done when the mature rice panicle ripened to a golden brown. It was harvested manually with sickle from a net

Table 1. Treatment combinations

Treatment Number	N	P	K
1	0		
2	40		
3	80		
4	120		
5	160		
6	0	15	
7	40	15	
8	80	15	
9	120	15	
10	160	15	
11	120	7.5	
12	120	22.5	
13	120	15	10
14	120	15	20
15	120	15	30

plot of 3m^2 and threshed. Harvested grains and straw were weighed and the grain yield calculated. Paddy yield was adjusted to 14% moisture content.

Statistical Analysis

All data collected were analyzed using Statistix 10 (Analytical Software, Tallahassee, FL). Analysis of variance was done using plot data for each location where replication and location were considered random effect and nutrient rates were considered fixed effects. Combined analysis of variance was conducted across locations. The means were separated using the Least Significant Difference (LSD) at 5% level of probability. location-treatment interaction were used to determine combined effect of each two.

RESULTS AND DISCUSSION

Grain yield response to applied nitrogen at Kadawa and Wushishi

The effect of nitrogen fertilization on grain yield presented in Table 2 shows that mean yield without nitrogen in Kadawa, Wushishi and the combined analysis were 2.6, 5.05 and 3.83 t/ha respectively. There were significant ($p<0.05$) increases in yield with N application in both locations and the combined analysis. 59% maximum yield increase was recorded in Wushishi with 80 kg/ha of N applied. 120 kg/ha of N produced maximum yield of 3.91 Mg/ha which corresponds to 50% yield increase in Kadawa. An increment of 1.91Mg/ha was observed in the combined analysis. The N xP interaction was not significant for both location and the combined analysis. There was a significant ($p<0.05$) L xN interaction because lowland rice was more responsive to all levels of nitrogen at Wushishi than Kadawa. The significant ($p<0.05$) response of grain yield to N application showed that N is a major limiting nutrient in lowland rice soils (Fairhust *et al.,* 2007; Ishaya and Dauda., 2010). Similar yield increases have been reported by Fagaria *et al.* (2011). The predicted mean optimum N rate 3.4 and 6.9 t/ha for Kadawa and Wushish were higher than national recommendation and lower than those reported by Fagaria *et al.,* (2011). The greater crop response to applied nitrogen in Wushishi compared to Kadawa may be attributed to soil properties. The soil texture in Wushishi was clay loam which is typical of lowland ecology. Kadawa however had much coarse texture soil that was highly drained and consequently promoted leaching of applied N and moisture stress.

The effect of soil texture was so obvious that the control yield in Wushishi was more than highest yield with nitrogen application in Kadawa. This phenomenon also explained the observed location-nitrogen interaction on straw yield, and biomass and harvest index. Even though straw yield and biomass were significantly ($p<0.05$) higher in Wushishi, Kadawa appeared to have had significantly higher harvest index ($p<0.05$). Moderate moisture stress during grain filling promotes early plant senescence and remobilization of pre-stored carbon reserve from straw to grain (Yang and Zhang 2010). The maintenance of standing water during grain filling in Wushishi may have delayed senescence and poor partitioning of photosynthates into grain thereby leading to the relatively low harvest index.

Grain yield response to applied phosphorus at Kadawa, Wushishi

A 17% significant ($p<0.05$) yield reduction was observed with the application of 15kg/ha of P in Wushishi (Table 3). The depression was to such an extent that the yield in the control plot was significant because grain yield response to every P rate in Wushishi was significantly higher than same rates in Kadawa. Averaged across P rates, paddy yield response to phosphorus in Wushishi was significantly higher than Kadawa. The result from Kadawa lends credence to the non-significant yield increase observed in the same location by (Jibrin *et al.*,

Table 2. Paddy yield response to applied nitrogen at Kadawa and Wushishi.

Treatments	Location		
	Kadawa	**Wushishi**	**Combined**
Nitrogen (N) kg ha^{-1}		ton ha^{-1}	
0	2.60	5.05	3.83
40	3.55	7.05	5.30
80	3.42	8.05	5.74
120	3.91	6.97	5.44
160	3.51	7.63	5.57
Mean	3.4	6.95	
Interaction			
N x P	NS	NS	NS
LSD (L X N)		0.74	

NS = not significant at 5% level of probability.

2010). The observed yield decrease in Wushishi with P application has been reported by several studies. Zaman *et al.* (1995) and Ni-wuzhong *et al.* (2007) also reported decrease in the number of filled spikelets per panicle and 1000 grain weight with P application. The decrease in yield with application of 15 kg/ha of P could be associated with phosphorus–induced zinc deficiency which can be linked to soil reaction or crop physiology. The application of phosphorus-based fertilizer to soil that is marginal in zinc may stimulate zinc deficiency due to increase in pH of acid soils after flooding, leading to the precipitation of Zn as franklinite or sphalerite (Havlin *et al.,*2014). In a study on soils of Nigerian savannah, Agbenin (1998) observed significant zinc sorption with P application either as a result of precipitation or formation of zinc-phosphate complex on the surface of iron and aluminum oxides. The effect of phosphorus on zinc and other trace elements were also observed by Ugbaje and Abdu (2013), Saeed and Fox (1979); and Boll and *et al.,* (1977). The consequence of such reaction is decreased solubility and availability of Zn for root uptake.

Grain yield response to applied potassium at Kadawa, Wushishi

Yield response to applied K was not significant in both locations and the combined analysis (Table 4). However, there was a significant ($p<0.05$) location-potassium interaction because grain yield response to K was higher for all treatment levels in Wushishi than Kadawa. Average across treatment levels, Wushishi had significant higher yield than Kadawa. As expected, the soils of the experimental site appeared to have moderate exchangeable potassium indicating little or no crop response to applied K and can also be attributed to adequate indigenous nutrient supply from irrigation water, sediment deposits or fertilizer application from

Table 3. Paddy yield response to applied Phosphorus in Kadawa, Wushishi

Treatments	**Locations**		
	Kadawa	**Wushishi**	**Combined**
Phosphorus (P) kg ha^{-1}		ton ha^{-1}	
0	4.08	7.64	5.86
7.5	3.35	8.91	6.13
15	3.74	6.27	5.01
22.5	4.39	7.40	5.89
Mean	3.89	7.56	
Interaction			
L x P	1.32	NS	0.73
LSD (L X N)		0.91	

NS = not significant at 5% level of probability.

Table 4. Paddy yield response to applied Potassium at Kadawa and Wushishi

Treatments	**Location**		
	Kadawa	**Wushishi**	**Combined**
Potassium (K) kg ha^{-1}		ton ha^{-1}	
0	3.74	6.29	5.01
10	4.19	7.96	6.08
20	4.09	8.32	6.20
30	3.98	7.73	5.85
Mean	4.0	7.52	
Interaction			
L x P	NS	NS	NS
LSD (L X N)		1.58	

NS = not significant at 5% level of probability.

previous trials and inherent abundance of K content in the savanna soils. Soilmoisture, as stated earlier, alsoinfluenced the significant location-potassium interaction observed in this study.

CONCLUSION

Results of this study showed that N and P application significantly increased grain yield of rice. At both locations, the highest yields were obtained when balanced N, P and K fertilization was used to overcome deficiencies and maintain soil fertility. Nitrogen, and to a lesser extent P, is a major limiting nutrient in the irrigated lowlands in the Sudan and Guinea savannahs of Nigeria. For high rice yield levels, it is necessary to adjust fertilizer rates on a more site-specific basis. Higher levels of N in the irrigated lowland and higher P and K may be required than recommended. Potash fertilizers have little effect especially in the irrigated lowlands. Further research with varying application rates of fertilizer N, P and K and other micronutrients will be necessary over a number of years to determine the most economic site-specific nutrient management options.

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