Original Research Article

EFFECTS OF SOIL FERTILITY STATUS ANDITS MANAGEMENT ON PRODUCTIVITY OF RICE IN FLOODPLAINS OF WUKARI, TARABA STATE, NIGERIA

ABSTRACT

An experiment was carried out to determine the soil fertility status and productivity of rice on flood plain soils at different locations in Wukari LGA of Taraba State in thesouthern guinea Savanna zone of Nigeria. The treatments consisted of five locations (Gidan-Idi,Gindin-Dorowa,Tsokundi**,** Rafin-Kada and Nwuko)that was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. The field was cleared, ploughed and harrowed, and marked into plots of 5 m x 5 m with an alley of 1 m between replications and 0.5 m between plots. Rice seeds (faro 44 (sipi 6920233)) were sown by dibbling at 25cm×20cm intra row. Nitrogen fertilizer was applied (at 3 to 4 weeks after planting as urea at the rate of 120 kgN ha^{-1}) by top dressing method. Phosphorus fertilizer was also applied at 5 to 8 weeks after planting in split doses at the rate of 40 kg P_2O_5 ha^{-1} as single super phosphate and Potassium oxide fertilizer was applied 10 to 12 weeks after planting at 40 kg K_2O ha^{-1} by top dressing method. Soil and plant data were collected and analyzed using standard procedures.The results were subjected to analysis of variance and means separated using F-LSD test. Significant ($P \leq 0.05$) differences in plant height and grain yield were observed during 2016 and 2017. Rafin-Kadarecorded the highest grain yield of 8.36 tons/ha while Nwuko recorded lowest grain yield of 7.43 tons/ha in 2016. Gidan-Idi recorded the highest grain yield of 8.33 tons/ha while Gindin-Dorowa recorded lowest grain yield of 7.41 tons/ha in 2017.

KEY WORDS: Productivity,Flood Plain, Soil Fertility Status, Rice.

INTRODUCTION

Flood plain soils are found generally adjacent to major rivers or streams. These soils are highly heterogeneous in fertility status due to the hydromorphic environment in which they are formed(Effiong and Ibia, 2009). Flood plain soils as a natural resource can only be properly managed with proper understanding of its characteristics (Idoga*et al*., 2005). The agricultural productive potentials of river banks and floodplains such as the Nile valley have been identified as the origin of great human civilizations (Carating*et al*., 2014). Floodplain soils tend to be more fertile than adjoining upland areas and availability due to better water holding capacity makes them suitable for year-round cropping (Ogban andBabalola, 2009). Despite their potentials, the flood plain soils in Nigeria are largely underutilized. The complex nature of these soils, arduous agronomic task on management coupled with inadequate information on these soils in Nigeria has contributed to their underutilization (Ukabiala, 2012).

Rice is grown on 156 × 10^6ha with theproduction capacity of 660 × 10^6tonsworldwide (Dengiz, 2013). Rice is not onlythe staple food for nearly half of the world's population asthe major daily source of calories and protein, but is alsoa key source of employment and income for rural people(FAO, 2003). Rice is important in Nigeria for several reasons. It is a major contributor to internal and sub-regional trade.Rice is the staple for most of the peoples in the Niger-Benue trough which divides Nigeria into fourparts, Sokoto-Rima Basin in the north-west, Chad

Depression in the north-east, Hadejia-Jamaare trough in the extreme north, and Cross River trough in the south. Farmers find rice more adaptable than a high inputrequiring crops maize especially when there is declining soil fertility because of the huge array of varieties they can switchover to every year. Since it is becoming a staple crop, farmers seem to be willing to grow it all the timeno matter the constraints they are facing.

Crops such as rice, tomatoes, sorrel, amarantus, cabbage, sesame, okra, pepper and onions are largely cultivated under irrigation on the floodplain soils in Nigeria. The floodplain soils potential is high in Taraba State, based on available area for irrigation and free of forest cover and requires no drainage. These areas have potential for irrigation, using underground and surface water; they remain still under-developed thereby limiting significant commercial activities. FAO (1986) indicated that better understanding of the soil within a potential irrigation area is essential for economic and technical reasons. The design of the irrigation scheme itself is dependent on detail knowledge of soils lying within the floodplain areas. Ojanuga*et al*. (1996) stated that wetland soils are grossly underutilized in Nigeria for any kind of purpose, especially in the drier Guinea, Sudan and Sahel savannas where wetlands are loci for permanent agriculture. This important crop like any other crop requires increased productivity through the use of appropriate variety. The use of local varieties has attracted less attention by farmers due to low yield. Problems of pest and disease were observed affecting the performance of the crop.

Soil productivity is the capacity of a soil in itsnatural environment to produce a specific plant orsequence of plants under specific systems of management.Efficient management of natural resources is essentialfor ensuring food supplies and sustainability in agriculturaldevelopment. The task of meeting demand withoutaffecting the ecological assets for future generations is being given top priority by both scientists and planners.There is an urgent need to match the land resources withthe current land use for sustainable production and to meetthe needs of society, while conserving fragile ecosystems(FAO, 1993).Therefore, this work was carried out toidentify the soil fertility status and productivity of rice on floodplains of Wukari, Taraba State, Nigeria.

The objectives of the study include; to determine the physical and chemical properties of soils of the study area and to evaluate the productivity of rice on the floodplains

MATERIALS AND METHODS

Experimental Site.

The experiment was conducted during 2016 and 2017 dry seasons at Wukari flood plain, Taraba State, North Eastern Nigeria (latitude $7^0$51’ Nr and longitude $9^0$47’ E). The area is sparsely populated, with an estimated population density of 19 to 22 peopleper km². Agriculture is the most important economic activity in the area, employing more than 90% of the labour force. Most of the farmers are subsistence oriented.

The area received an annual rainfall of 750 to 1600 mm. Rainfall distribution is unimodal, with much of the rain falling between May and October. The wettest months are August and September. The rainy season is followed by a long dry season. The temperature characteristics are typical of the West African savanna climate. Maximum temperature can reach 39°C particularly in April while minimum temperature can be as low as 18°C between December and January. The mean monthly temperature ranges from 26.7°C in the south to 27.8°C in the northeastern part. Humidity is generally lowest in the dry season about 20% and is very high in the wet season about 80% in August. An increase in the humidity always precedes the onset of the rains in May.

The area is richly supplied with a network of river and streams. Rivers Bantaje and Gindin-Dorowa form the major rivers and joined by numerous tributaries. The topography is generally flat, becoming undulating and hilly toward the northeast.

Experimental Details

The land was cleared, ploughed and harrowed. The field was marked intoplots of 5 m x 5 m with an alley of 0.5 m between plots and 1.0 m between replications. There were five locations,GidanIdi,GindinDorowa,Tsokundi**,** RafinKada and Nwuko) replicated three times and laid out in a Randomized Complete Block Design (RCBD). The total land area of the experiment was 230 m^2 in each location.

Land Preparation and Planting

Early maturing variety, Faro 44 (sipi 6920233) was obtained from the Liaison Office of the Value Chain Development Project Wukari for planting. Prior to sowing, the seeds were soaked in water to determine its viability through floating method. Planting was done by direct seeding at a depth of 2-4 cm.Dibbling was done at an approximate spacing of 25cm×20cm intra row.Nitrogen fertilizer was applied at 3 to 4 weeks after planting as urea at the rate of 120 kgN ha^{-1} by top dressing method. Phosphorus fertilizer was also applied at 5 to 8 weeks after planting in split doses at the rate of 40 kg P_2O_5 ha^{-1} as single super phosphate and Potassium oxide fertilizer was applied 10 to 12 weeks after planting at the rate of 40 kg K_2O ha^{-1} by top dressing method.Manual weeding was done regularly especially during early stages of growth. Harvesting was done when 80-85 % of the grains turned straw colour to avoid shattering (i.e. 4-5 weeks after 50% flowering). The rice stem was cut with sickle at about 15-20cm above the ground (to permit hand threshing).The panicles were tied in bundles and heaped for drying before threshing. The rice was dried to 12-14% moisture content before threshing.

Soil Sampling and Analysis

Composite soil samples were collected from the plots before planting and after the planting based on the treatments. The collected samples were used to determine soil physical and chemical properties. Particle size distribution was determined by Bouyoucos hydrometer method of mechanical analysis (Trout *et al.,* 1987). The bulk density was determined by the core Sampler Method of known soil volume (Fuller and Warrick, 1985).Available water holding capacity was determined with pressure plate apparatus as described by Singh*et al*. (2013). Soil pH was measured electrometrically using glass electrode pH meter in a solid-liquid ratio of 1:2.5 (Hendershot*et al.,* 1993). Total nitrogen was determined by macro-Kjeldahl digestion technique method (Bremner, 1996). Exchangeable bases were determined by the neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982). Exchangeable acidity was determined by a method described by McLean (1982). Organic carbon was analyzed by wet digestion and the organic carbon content was multiplied by factor1.724 to get the percentage organic matter (Nelson and Sommers, 1982). Available phosphorous was determined by Bray l method according to the procedure of Nelson and Sommers (1982). Cation Exchange Capacity was determined using neutral ammonium acetate leachate method (Summer and Miller, 1996). Base saturation was computed as Total exchangeable bases divided by Cation Exchange Capacity.

Plant Data Collection

Agronomic data collected includes plant height, leaf area index,grainyield per hectare and test weight.

Statistical Analysis

The experimental data were analyzed statistically usinganalysis of variance (ANOVA) to check for significant effects of studied parametersat 95% confidence limit using the procedure by Steel and Torrie (1980).When significant differences were observed, treatment means were separated using F-LSD. The analysis of variance (F-ratio) is a parametric test for significance among three or more variables. In this study, test for variations in the selected parameters over the different locations at different periods while the F-LSDtest was used to test for significant association between pairs of locations or periods.SPSS 17.0 software (SPSS inc., Chikago, IL, USA) was used for the statistical analysis.

RESULTS AND DISCUSSION

Soil status

The soil of the study area was clay loam in texture (Table1). Generally, the mean values of the soil textural analysis indicate that the clay fraction dominated the fine earth separate. This was closely followed by the sand fraction, while the silt fraction was lowest. The soil textures in these areas are mainly clay loam, which is medium texture. Bulk density of the flood plains had lowest mean value of 1.30g/cm^{3}and highest mean value of 1.33 g/cm^3.These values also agree with Brady (1990) that density of clay loam surface normally ranged from 1.00 to 1.60g/cm^3. The bulk density values of the flood plains were <1.6 g/cm^3, thus rated medium, a range considered adequate not to impede the plant root penetration (Donahue *et al*., 1990). The lowest value of mean available water recorded in the flood plains is 0.25m/m while the highest mean value is 0.28m/m. Generally, the available water capacity of these soils is low.

Data (Table 2) shows the mean soil chemical properties of the flood plain soils. The soil pH measured in water was neutral to slightly acidic indicating that the pH range is optimum for the cultivation of most crops, but proper management should be maintained in order to reduce the chances of alkalinity hazards. The soils of the flood plains had mean pH values range from 6.47 to 7.05. Soil reaction was slightly acidic to neutral (Malgwi, 2001). The value of the organic carbon content was of moderate(1.46 to 1.53%) indicating that the soil was moderate in organic matter content. The soils organic matter (OM) contents of the flood plains had highest mean value of 2.65 % and lowest mean value of 2.52 %. Organic matter is generally low in the soils according to Landon (1991) ratings (>20 % very high, 10-20 % high, 4-10 % medium, 2-4 % low and < 2 % very low). The nitrogen content of the soil was low (0.123 to 0.175%).The available phosphorus content of these soils is high with highest mean value of 18 % and lowest mean value of 16.20 %. These high values may be due to the fact that phosphorus is characteristically immobile, and tend to remain fixed at the clay micelle. The exchangeable bases comprised of exchangeable Ca, Mg, K and Na. Calcium was the dominant exchangeable base in all the soils.The exchangeable Ca in the flood plains was rated medium range, the range in value of magnesium were moderate, potassium values were generally in the medium range and sodium valueswere generally in the medium range. Generally, the exchangeable bases occurred in the order Ca>Mg>K>Na in all the flood plains, this corroborates earlier reports on soils of the Nigerian savannah (Raji, 1995).The exchange acidity comprises exchangeable hydrogen and exchangeable aluminium. The values were classified as generally in the medium range which suggests that the soils have little or no acidity problems, except for incipient acidity in some horizons. The CEC of Wukari flood plains were rated medium which matches with the findings of Adepetu*et al*. (1979) who reported cation exchange capacity values of < 6, 6 - 12 and > 12 cmol(+)/kg as low, medium and high respectively. Base saturation (BS) of the flood plains had highest mean value of 55.90 % and lowest mean value of 53.69 %. The values were rated moderate being generally between 50-80%. The medium values indicate that the soils have moderate potentials for supplying plant nutrients; hence, the necessity for adequate soil management required especially in the upland.

Table 1: Mean Soil Physical Properties of Wukari Flood Plains.

Soil Depth (cm)	Location	Particle Size Distribution % sand	% Silt	% clay	Textural class	Bulk density (g/cm^3)	WHC (m/m)
	NWRS	35.0	27.6	37.4	CL	1.32	0.27
	TSRS	37.0	25.7	36.9	CL	1.31	0.26
0-20	RKRS	39.1	24.9	36.7	CL	1.33	0.26
	GIRS	39.0	25.0	36.0	CL	1.32	0.25
	GDRS	35.1	27.5	37.4	CL	1.32	0.26
	NWRS	36.0	27.0	37.0	CL	1.31	0.27
	TSRS	36.7	26.3	37.0	CL	1.30	0.26
20-40	RKRS	37.7	26.3	36.0	CL	1.33	0.26
	GIRS	38.0	25.0	37.0	CL	1.32	0.26
	GDRS	35.5	27.1	37.4	CL	1.31	0.26
	NWRS	35.4	27.2	37.3	CL	1.31	0.26
	TSRS	37.0	26.0	37.0	CL	1.31	0.26
40-60	RKRS	37.0	27.0	36.0	CL	1.33	0.25
	GIRS	37.7	25.3	37.0	CL	1.31	0.27
	GDRS	35.5	27.1	37.4	CL	1.31	0.28

Table 2: Mean Soil Chemical Properties of Wukari Flood Plains

Depth (cm)	Locn	pH (H_2O)	EC dS/m	OC %	OM %	Total N %	Avail P %	K	Ca	MgNacmol(+)/kg		EA	CEC	BS %
	NWRS	6.73	1.23	1.46	2.52	0.165	16.20	0.32	4.3	0.81	0.21	5.15	10.79	52.1
	TSRS	7.03	1.27	1.48	2.56	0.123	17.00	0.26	4.1	0.73	0.23	4.78	10.13	52.8
0-20	RKRS	6.47	0.81	1.52	2.62	0.163	17.18	0.29	4.5	0.86	0.21	4.50	10.39	56.67
	GIRS	6.80	1.41	1.53	2.64	0.124	17.03	0.28	4.7	0.83	0.24	5.11	10.88	52.69
	GDRS	6.67	1.26	1.47	2.54	0.163	16.88	0.29	4.7	0.82	0.23	4.51	10.55	57.33
	NWRS	6.83	1.23	1.46	2.51	0.175	16.20	0.31	4.3	0.80	0.25	5.94	11.59	48.7
	TSRS	7.03	1.27	1.48	2.56	0.125	18.00	0.27	4.2	0.73	0.24	4.85	10.28	52.9
20-40	RKRS	6.64	0.82	1.53	2.64	0.164	17.05	0.28	4.6	0.86	0.22	4.52	10.46	56.59
	GIRS	6.81	1.42	1.53	2.64	0.125	16.87	0.29	4.6	0.82	0.24	5.17	11.12	55.57
	GDRS	6.78	1.26	1.47	2.53	0.163	16.97	0.28	4.6	0.82	0.25	4.52	10.53	57.13
	NWRS	6.82	1.31	1.43	2.47	0.173	17.20	0.32	4.5	0.83	0.25	5.16	11.09	53.4
	TSRS	7.05	1.26	1.51	2.56	0.126	17.74	0.26	4.2	0.72	0.23	4.87	10.28	52.6
40-60	RKRS	6.88	0.79	1.53	2.65	0.166	17.01	0.29	4.6	0.86	0.22	4.49	10.45	57.04
	GIRS	6.81	1.42	1.53	2.64	0.125	16.93	0.30	4.7	0.83	0.24	5.14	11.22	54.23
	GDRS	6.81	1.26	1.47	2.53	0.131	16.47	0.29	4.7	0.80	0.23	4.51	10.44	56.84

Key: NWRS-Nwuko floodplains, TSRS-Tsokundi floodplains, RKRS-Rafinkada floodplains, GIRS-Gidan-Idi Floodplains NWRS-Nwoko flood plains.

Table 3: Mean Rice Growth and Yield Parameters

Year	Locations	Plant Height at Harvest (cm)	LAI at 42 DAP	LAI at 63 DAP	Grain Yield (t/ha)	Weights of 1000 Grains (g)
	Nwuko	89.00	4.2	11.2	7.43	26.95
	Tsokundi	86.87	4.3	9.3	8.33	26.53
2016	Rafin-Kada	85.97	4.0	10.7	8.36	25.80
	Gidan-Idi	91.20	4.3	9.9	8.00	27.08
	Gindin-Dorowa	91.17	4.4	11.3	7.92	26.92
	F-LSD $_{0.05}$	2.984	-	-	0.598	-
	Nwuko	89.84	5.0	11.5	7.82	27.42
	Tsokundi	89.77	4.0	10.7	7.84	26.95
2017	Rafin-Kada	87.37	5.7	10.4	8.07	26.78
	Gidan-Idi	98.37	5.9	12.0	8.33	27.39
	Gindin-Dorowa	107.07	5.6	10.2	7.41	26.78
	F-LSD $_{0.05}$	10.07	-	-	-	-

Rice Productivity within the Locations

The plant growth parameters analyzed are plant height (cm), leaf area index at 42 days after planting (LAI at 42 DAP) and leaf area indexes at 63 days after planting (LAI at 63 DAP) while the yield parameters analyzed are grain yield t/ha and test weight (g).

Plant height

The results of the plant height from the flood plains showed thatNwuko flood plain had a meanplant height of 89 cm in 2016 and 89.84cm in 2017;Tsokundi flood plain had a mean plant height of86.877cm in 2016 and 89.77cm in 2017; Rafin-Kada flood plainhad mean plant height of85.97cm in 2016 and 87.37cm in 2017; Gidan-Idi flood plain had mean plant height of91.27cm in 2016 and 98.37cm in 2017 and Gindin-Dorowa flood plain had mean plant height of91.17cm in 2016 and 107.07cm in 2017.

The highest mean rice plant height among the flood plains was 107.07cm in 2017 at GindinDorowa and the lowest was 85.97ncm in 2016 at RafinKada. The ANOVA test confirms the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level for both the periods studied. The analysis of means using F-LSD at $P \leq 0.05$ showed that most of the location means are statistically different.

Leaf area index (LAI)

The results showed thatNwuko flood plain had mean LAI at 42 days after planting (DAP) of 4.2 in 2016 and 5.0 in 2017;Tsokundi flood plain had 4.3 in 2016 and 4.0 in 2017; Rafin-Kadahad4.0 in 2016 and 5.7 in 2017; Gidan-Idi flood plain had 4.3 in 2016 and 5.9 in 2017 and Gindin-Dorowa flood plain had mean leaf area indexes at 42 DAP of4.4 in 2016 and 5.6 in 2017.

The highest mean LAI at 42 DAP of the flood plains was 5.9 at Gidan Idi in 2017 and the lowest was 4.0 in Rafin-Kada in the year 2016. The Analysis of Variance (ANOVA) test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically not significant at 0.05 probability level for both the periods studied (Table, 3).

The results also indicated that Nwuko flood plain had meanleaf area index (at 63 DAP) of 11.2 in 2016 and 11.5 in 2017;Tsokundi flood plain had9.3 in 2016 and 10.9 in 2017; Rafin-Kada flood plainhad 10.7 in 2016 and 10.4 in 2017; Gidan-Idi flood plain had 9.9 in 2016 and 12.0 in 2017 and Gindin-Dorowahad11.3 in 2016 and 10.7 in 2017 (Table, 3).

The highest mean leaf area index at 63 (DAP) was 12.0in 2017 at Gidan-Idi while the lowest was 9.3 in 2016 at Tsokundi.The ANOVA showed that the rice leaf area index at 63 DAPS were not significantly different for the different locations investigated ($P \leq 0.05$ level of significance) for both periods.

Grain yield per hectare

The results reveal that (Table 3)the grain yield fromNwuko flood plain was of 7.42 t/ha in 2016 and 7.82t/ha in 2017;Tsokundi flood plain had mean grain yield of8.33t/ha in 2016 and 7.84t/ha in 2017; Rafin-Kada flood plainhad 7.36t/ha in 2016 and 8.02t/ha in 2017; Gidan-Idi had 8.00t/ha in 2016 and 8.33t/ha in 2017 whileGindin-Dorowa had mean grain yields of7.92t/ha in 2016 and 7.4 t/ha in 2017.

The highest mean rice grain yield of the flood plains was 8.36t/ha obtained from Rafin-kada in 2016 and the lowest mean rice grain yield of the flood plainswas 7.41 t/ha obtained from Gidan-Idi in 2017.The ANOVA showed that rice grain yield of the floodplains were significantly different for the different locations investigated ($P \leq 0.05$ level of significance) in 2016 but were not significantly different for the different locations($P \leq 0.05$ level of significance) in 2017. The means separation using F-LSD at 0.05 probability level showed that the differences among some of the mean rice grain yield of the floodplain locations are statistically significant.

Test weight (g)

The results of the 1000 grain weight showed thatNwuko flood plain had 6.95 g in 2016 and 27.42g in 2017;Tsokundi had mean thousand (1000) grain weights of26.53g in 2016 and 26.95g in 2017; Rafin-Kada had25.80g in 2016 and 26.78g in 2017; Gidan-Idi had27.08g in 2016 and 27.39g in 2017 and Gindin-Dorowahad26.92g in 2016 and 26.78g in 2017 (Table, 3).

The highest mean test weight of rice was 27.42g at Nwuko and the lowest was 25.80g at Rafin-kada. The 1000 grain weight is a factor of the weight of grain and the number of the grain (1000). This implies that the result depends on the weight individual seeds. A plant with the lowest yield but few grains can still have higher 1000 grain weight than a plant with higher grain weight but more grains (Singh *et al.*, 2013). Sometimes rice plants accelerate the phase of vegetative development under nutrient and water stress and push more grain filling at the expense of vegetative development. In other words, every available photosynthetic product is pushed to sinks and these can increase the grain weight (Murtala, 1967).The ANOVA showed that the one thousand (1000) grain weights were not significantly different for the different locations investigated ($P \leq 0.05$ level of significance) for both periods of study.

Conclusion

The soils of Wukari Floodplains are mostly clay loam in texture having very slightly acid to neutral soil reaction, moderate organic matter, low total N, available P, exchangeable bases and CEC. This indicates that if adequate soil management practices are not employed, these soils will deteriorate and may not support sustainable crop production.

The flood plain soils were moderate in fertility, a confirmation of the general characteristics of Savanna soils reported by earlier researchers. There were significant variations among the flood plain soils at the different locations. They are highly to marginally suitable for rice productionbased on the quantitative method as this method considered permanent factors which are not easily changed. It has implication on land productivity of Wukari to meet food and fiber demand of the growing population.This study had revealed the possible sodicity status of the soils of the area and there is need for their proper management. It also revealed information on the limitation of the soils for sustainable rice production. The study also impliesthat low input was responsible for low outputs recorded by most farmers in the study area.

Recommendations.

On the basis of the two year study, the rice growers of the 4 floodplains of Nigeria are recommended to adopt the measures such as the return of crop residues and organic manure addition, minimization of tillage operation, introduction of viable crop rotation techniques and judicious application of chemical fertilizers must be adopted to sustain the fertility and continued productivity of these soils. The water sources used for irrigating the floodplains are relatively safe hence little or no treatment for soluble salts is required.

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