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Mineralogy profile of some rice irrigation water in Southern Nigeria

[1] William Ubi, [2] Godwin Michael Ubi, [3] Ackley Ufot Akpan-Idiok, [4] Thomas Okweche

[1, 4] Department of Science and Technology, National Open University of Nigeria, Calabar Study Centre, Nigeria
[2] Department of Genetics and Biotechnology. University of Calabar, Nigeria
[3] Department of Soil Science, University of Calabar, Nigeria

Abstract

Experiments were conducted in 2013, 2014 and 2015 on the quality of some rice irrigation water at Adim, Idomi, Assiga and Ofodua in Cross River State, Southern Nigeria to determine their rate of nutrient supply. The results showed that Adim location was more acidic with pH range of 4.5 to 5.6 with a mean of 5.1 on the average, compared with a pH of 6.1 each for either idomi, Assiga or Ofodua. The Ca, Mg and K values were moderate and will not be a problem to rice cultivation. A minimum of about 1/8 of the Ca and 1/3 of Mg were removed from the grain. The amount of K used by the plant in the water culture experiment was much higher than those of Ca and Mg. The N in irrigation water was relatively high in all the study areas and the amount removed in grain was considerable. The four irrigation waters studied were found to have good supply of these elements and deficiency will not be a problem for rice production. The supply of P by irrigation water was moderate to low in the four study areas, but the highest value was found at Ofodua. Culture solutions used very much larger quantities of phosphorus and more than 10.2% of total P was found in the grain. The conductivity was much less than 1000 x 10^6 Mhos, which is the toxic level for rice, and will not be detrimental to good yields of rice. The mean value of N:P:K:, Ca, Mg, Mn and Fe were significantly ($p<0.05$) higher in the straw than in the grain in all the samples studied. Comparing the mean values of Mn with those of Fe, Mn values were more than double those of Fe throughout the study period.

Keywords: Mineral content, Irrigation water, Oryza sativa, Essential nutrients.

Introduction

Rice grain (caryopsis) although can be grown in war temperature countries but it is essentially a topical and sub-tropical crop (Mitsui, 1986; Sugimoto, 1999; Ubi *et al.*, 2016c) [15, 24, 26]. It is adapted to warm high humidity and in most cases, swampy conditions, cultivated between latitude 45ºN and 45 ºS, and required tempered of 21.1 ºC (Pearson, 1993) [19]. In considering the supply of nutrients to rice fields, (Allen, 1965; Passwater, 1999) [1] pointed out that the supply of nutrients by irrigation water is one of the characteristics features of the lowland rice as compared with upland rice. In some areas of Cross River State, rice fields have been grown for more than a century with good yield without any fertilization and it is suspected that the major sources of nutrients supply are few. Information obtained from this study will be important in understanding the direct relationship between irrigation water and plant nutrients as it affects production. It was in consideration of this that this study was undertaken with the aim of defining the state of current knowledge on:

1. The supply of nutrient elements of irrigation water to padi.
2. The impart on rice product.

Materials and Methods

Four locations from the central area of Cross River State in Southern Nigeria were examined. The experimental areas are bounded by longitude 5º14'N and 5º18'E and latitude 8º14'N and 8º20E, extending from Idomi, Adim, Assiga to Ofodua, in the central fringe of the state. The mean annual rainfall in most part of the central Cross River State is 2500mm (ranging from 2250 to 1700mm), while its distribution is bimodal with a dry season of 4 months between November and March. Mean daily minimum and maximum temperatures vary from 21 ºC to 24 ºC and 27 ºC to 32 ºC respectively, while relative humidity varies from 82 to 97% (Eshett, 1994). Most of the irrigation waters in the four study areas have tidal mudflats and water logged soils in which Panicle maximum (S112) was the dominant floral species.

Collection of Samples

Samples of water about 2 litres were taken from each rice field at Idomi, Adim, Assiga and Ofodua during the growing season and before planting in many of each year for a period of three years. Water from the local waste dumps and animals faces which drained into the rice fields at Adim, and drains from heaps of cassava peels fermented beside the spill way at Idomi were sampled systematically. Domestic waters included kitchen waste, environmental wastes like leaves from plants, palm oil sludge, domestic material and faeces.

The water samples were analyzed for total solids, pH, total Nitrogen, Phospherus, Potassium, Calcium, Magnesium Sulphate, Chloride and conductivity using, the procedure curtained in Ameridan Public Health Association, (Methods of analysis of sewage) (APHA, 1995). Except that the conditioning reagents were those described in a modification of the original procedure (1971). Where conductivity values were above 167x10-6 Mhos, sulphate and chlorine were determined.

Experiment Two

In order to interpret the results from irrigation water analysis very well, it was useful to conduct a second experiment, using three solutions of water culture for the growth and development of rice (Ubi *et al.*, 2016c) [16].

The following solution concentrations were prepared and used for the study

Table 1: Solution Concentrations

Solution	N (g/kg)	P (mg/kg)	K (cmolkg^{-1})	Ca (cmolkg^{-1})	Mg (cmolkg^{-1})	Fe (cmolkg ^{1})
Fine conc.	21	8	18	10	7	3.7
Variable conc.	24	5-12	13-21	8-14	4-9	1.2-2.0
Low conc.	12	6.3	16	7.5	4.3	1.4

Solutions were prepared from the following: NPK Mg from N, P, K, Mg 12:12:17:2
Fertilizer: Ca from $CaSO_4$; Fe from $FeSO_4$.

Experimental Materials

1. Rice variety – faro 15
2. Concentration levels
(a) Fine concentration
(b) Variable concentration
(c) Low concentration (See Table 1).

Nursery Establishment

Land was cleared packed and removed, stumps were removed and the area leveled uniformly. The rice variety "FARO 15", was collected from international institute for tropical Agriculture (IITA), and was broadcast evenly on a nursery size of 50 x 40m (20, 000sq.m), covered with palm fronts against rodents and birds. Planting was done in April 9, for each of the three years 2013, 2014 and 2015.

Field Planting

The three months seedlings were transplanted into polyethylene bags weighing 5kg, perforated at the bottom and filled with soil fertilized with 2gm each of N, P_2O_5 and K_2O at the beginning of the study.

Experimental Design

A randomized compete block design was used, replicated three times with one hundred and fifty polyethylene bags giving fifty bags per replication measuring 50 x 5m with sampling area of 2^2m, per plot.

Culture Experiment

Three culture solutions of fine concentration, variable concentration and low concentration were assigned randomly using a spraying pump. The application of culture solutions commenced one month after transplanting and continued every four weeks until the crop matured. At maturity of the crop, harvest was done with harvesting sickle and panicles harvested were threshed, winnowed and dried in Gallen kamp laboratory oven, at temperature of 72 ^{o}C for 48 hours to a moisture content of 10% and then weighed. Both straw and rice grains were ground to powder independently and stored in dry plastic bottles for laboratory analysis, using the methods of Association of Official Analytical Chemists, (AOAC, 1998) [2].

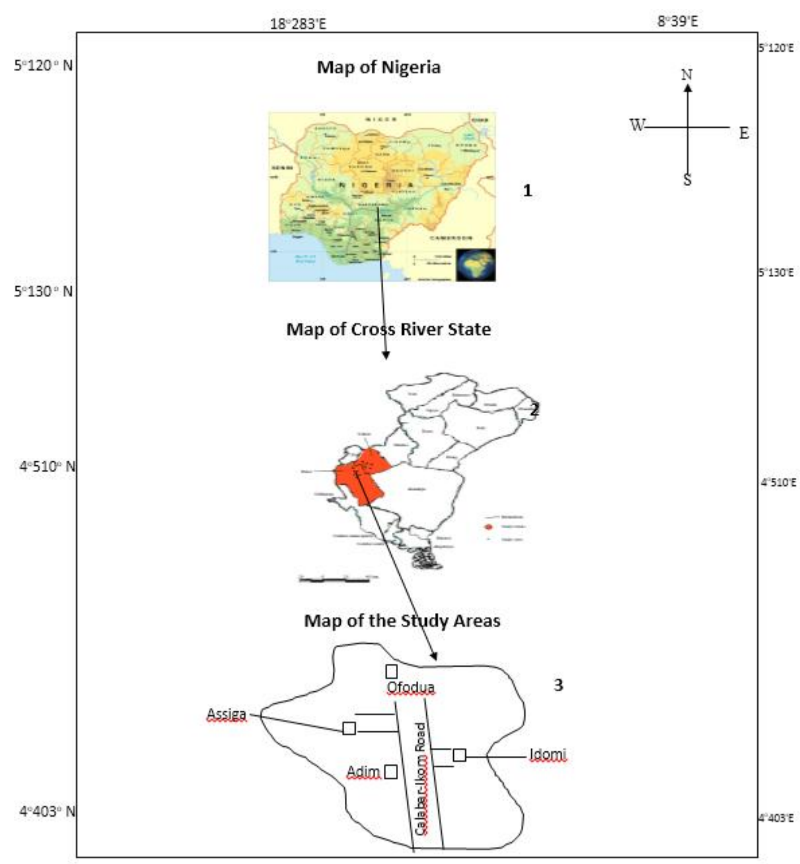

Fig 1: Maps showing experimental site

Table 2: Water Analysis from four padi stations

Location	Approx. distance from river	Year	pH	Total N (g/kg)	NH_4-N (cmolkg)	P (mg/kg)	Exchangeable Bases Ca (cmol/kg)	Mg (cmol/kkg)	(cmol/kg)	Na (cmol/kg)	Conduct Mhos 10^{-6}	Sulphate (cmol/kg)	Chloride (cmol/kg)
Adim	3 kilometers	2013	5.2	2.78	0.85	0.26	3.46	4.12	2.62	0.31	122	40.92	48.73
		2014	5.6	2.82	0.76	0.35	3.74	4.87	2.14	0.46	187	39.44	67.64
		2015	4.5	2.76	0.75	0.58	5.82	5.17	3.28	0.52	218	48.56	38.10
		Mean	5.1	2.79	0.79	0.40	4.34	4.73	2.64	0.43	175.7	42.97	5.15
Idomi	4.2 kilometers	2013	6.0	2.65	0.75	0.34	4.17	4.71	3.71	0.33	218	9.24	58.95
		2014	6.3	2.80	0.68	0.46	5.36	5.62	3.11	0.40	301	27.52	69.76
		2015	6.0	2.68	0.59	0.39	5.72	4.85	4.20	0.39	306	35.93	78.92
		Mean	6.4	2.71	0.67	0.39	5.08	5.06	3.67	0.37	275.0	17.56	69.21
Assiga	2.8 kilometers	2013	6.0	2.72	0.89	0.45	5.79	4.92	4.12	0.36	310	10.86	67.99
		2014	6.2	2.69	0.76	0.37	5.82	5.58	3.81	0.41	329	28.94	76.94
		2015	6.2	2.78	0.65	0.36	4.31	6.73	4.33	0.38	338	39.62	84.72
		Mean	6.2	2.73	0.77	0.39	5.31	5.74	4.09	0.38	325.7	26.47	76.55
Ofodua	1.5 kilometers	2013	6.2	2.81	0.88	0.46	5.86	4.75	4.10	0.41	329	24.91	61.52
		2014	6.0	2.77	0.79	0.39	4.59	5.66	3.19	0.39	384	38.54	68.15
		2015	6.1	2.91	0.84	0.44	5.67	4.97	4.38	0.47	336	26.34	72.84
		Mean	6.1	2.82	0.83	0.43	5.37	5.13	3.89	0.42	349.7	32.57	67.50
		L.S.D.	0.3	0.2	0.03	0.03	0.42	0.42	0.3	0.02	0.61	5.72	4.76

Table 3: Nutrients in Kg taken up in straw and grain to produce 100kg of padi (results from 50 samples)

Parameter	N	P	K	Ca	Mg	Mn	Fe
Grain	7.0	1.40	1.15	1.24	0.82	0.18	0.06
Straw	8.3	2.22	10.12	2.48	0.59	0.26	0.12
Total	12.3	3.62	11.27	3.42	1.41	0.44	0.18
% in grain	82.0	10.2	9.4	12.6	35.1	8.3	7.5
LSD	2.1	0.20	3.8	0.82	0.03	0.02	0.02

Table 4: Nutrients in Kg taken up in grain and straw to produce 100kg of padi (results from 20 samples)

Parameter	N	P	K	Ca	Mg	Mn	Fe
Grain	6.18	0.48	1.31	0.58	0.63	0.08	0.04
Straw	6.76	1.26	10.12	1.87	7.65	0.53	0.25
Total	12.94	0.74	11.43	2.45	8.28	0.61	0.29
% in grain	79.4	26.0	13.2	28.4	34.5	10.2	6.3
LSD	1.6	0.5	6.2	0.32	3.5	0.03	0.02

Results and Discussion

pH of the Solution

The results in Table 2 shows that the pH of irrigation water at Adim was the lowest ranging between 4.5 and 5.6 with a mean of 5.1. The mean values obtained from those of Idomi, Ofodua and Assiga on the average were 6.4, 6.2 and 6.1 respectively. The high acidity values for Adim study area could be attributed to the present of high sulphate derivable from domestic waste and the acidity is suggested to be proportional to the amount of sulphate present in the water. Rice plants do not tolerate acidity below pH 3.0 critical level (Allen, 2001; Akeleye *et al.*, 2002). In general, it may be suggested that irrigation water below a pH of 3.5 may be unsuitable for rice growth in Adim as yields of rice could be reduced due to sulphur accumulation (Phene, 1989; Raemaeker, 2001; FAO, 1988; Ubi *et al.*, 2016a) [20, 27]. In tropical soils such as oxisols and ultisols with pH values below 5.0, exchangeable Al plays a dominant role in soil acidity, which in turn influences crop growth due to its toxicity. The results in this study indicate that Al toxicity will not be a problem.

Nitrogen (g/kg^{-1})

The N content was high at least above the critical level of 2.0g/kg (Juo, 1981) [12]. The mean values obtained from the four study areas were similar, indicating that N will not be a problem to rice production. The high amount of total N reflects organic carbon contents and degree of net mineralization of nitrogen (Paul and Clark, 1989) [18].

Calcium, Magnesium and Potassium (cmol/kg^{-1})

Table 2 shows values of Ca, Mg and K in which values of Ca were moderate to high with means of 4.34, 5.08, 5.31 and 5.37 (cmolkg^{-1}) for Adim, Idomi, Assiga and Ofodua. The K mean values were 2.64, 3.67, 4.09 and 3.89 (cmolkg^{-1}) for Adim, Idomi, Assiga and Ofodua respectively. The mean values for Mg were 4.731, 5.06, 5.74 and 5.13 (cmolkg^{-1}) for Adim, Idomi, Assiga and Ofodua respectively. The mean values of Na were 0.43, 0.37, 0.38 and 0.42 (cmolkg^{-1}) for Adim, Idomi, Assiga and Ofodua respectively. These values are above their critical values reported by Juo (1981) [12] indicating that deficiencies will not be a problem.

The results of nutrients in Kg taken up in straw and grain to produce 100kg of padi (mean of 50 samples) are presented in Table 3. Nitrogen, Potassium, Phosphorus, Calcium, Magnesium, Manganese and Iron, all had higher values of their contents in the straw than in the grain. Taking the average of nutrients in both straw and grain, nitrogen had the highest mean value of 12.3g/kg indicating 239% unit increase $\frac{12.3-3.62}{3.62}\times 100,$ compared with the value of phosphorus, and 231% unit increase $\frac{12-3.77}{3.72}\times 100,$ when compared with calcium under similar experimental conditions (Table 3). The percentage of nitrogen in the grain 82g/kg (in 50 samples) and 79gkg in 20 samples were significantly (p<0.05) higher than all other values from other nutrients throughout the study season. Ranking nutrients in terms of their values in straw and grain on the average (for 50 samples) we have: N>Mg>Ca>*P*>N>Mn>Fe. Ranking the nutrients in terms of the percentages in the grain with 20 samples gave a similar trend with that of 50 samples, indicating that the uptake of nitrogen was significantly higher than values of either P, K, Ca, Mg, Mn or Fe under similar experimental condition (Allen 2001; Akeleye *et al.*, 2002).

A maximum of about 1/8 of the Ca and 1/3 of Mg were removed from the grain Table 4. It could be suggested from the result that a supply of 1 cmol (4)kg^{-1} Ca and Mg would compensate for the removal of Ca and Mg by the grain. The irrigation water from the study areas showed high amounts of Ca and Mg and their deficiencies would not be experience in the rice growing areas studied. Interestingly was the fact that the values of Ca, Mg and K obtained in this study were above their critical values of 4.0$cmolkg^{-1}$; 0.5$cmolkg^{-1}$ and 0.2$cmolkgh^{-1}$ respectively (Juo, 1989).

The amount of K used in water culture that was taken up by the plant was much higher than those of Ca and Mg, but only a percent of these was removed in the grain (Hudges and Avery, 1977; Vergara *et al.*, 1995; Later, 2005) [11, 28, 14]. With regards to Ca and K, the four irrigation waters studied have good supply of these elements, and deficiency would not be a problem.

Phosphorus P

The supply of P by irrigation water was moderate to low in the four locations (Table 1), culture solutions used gave very much larger values of P, and more than 10.2 percent of total P was found in the grain, or was removed (Table 3). Except a soil has initially very large reserves of P, it will likely respond to phosphate fertilizers (Ashraf *et al.*, 1981 and Allen, 2001). The mean values of P obtained at Ofodua study area were significantly (p<0.05) higher than all other values under similar experimental condition, indicating that there was no fixation of P by Fe and Al or even Mn under drain, water or acidic conditions in the soils, (Onyekwere *et al.*, 2001; Ubi *et al.*, 2016a) [16 , 27].

Sulphates, Chloride and Conductivity

Sulphur is necessary for plant growth and it has been found that minute quantities of chorine might be essential (Ashraf *et al.*, 1992; Coffin *et al.*, 1999; Ebong *et al.*, 2004) [4, 5, 8]. The decomposition of domestic wastes which invariably contain sulphur released sulphates which could be to carried to the rice fields by irrigation water. The study has shown that deficiency of sulphur and chorine were not reported, but excess of sulphur and chloride in the forms of sulphate and chloride could be a problem at Adim location, because the mean value of 42.87 was more than double, the value from Idomi and significantly (p<0.05) higher than values of either Assiga or ofodua.

The presence of large amount of sulphates and chlorides in the waters from domestic waste Adim denotes poor drainage conditions or consternation with river water. Rice plants generally can tolerate some amount of soluble salt, but large amounts indicated by conductivity of more than 1000 x 10^{-6}. Mhos are detrimental to good yield of rice (FAO, 1990; Reddy and Hot Wani, 1993; Ubi *et al.*, 2016b) [9, 23, 25].

The NH4-N values were variable and the variability was significant (p<0.05), the highest value came from Ofodua (0.83g/kg) while the lowest came from Idomi (0.67g/kg). Among the micro nutrients, values of Mn were higher than those of Fe, given similar experimental condition. The values of Mn and Fe reported in this study compare favorably well with mean values reported for related Nigerian soils (Cotteinie *et al.*, 1981; Ubi *et al.*, 2016b) [6, 25].

Acid Water

The irrigation water at Adim is a special case of acid irrigation water. The pH of the water during normal year was 5.1 compared with values from either Idomi, Assiga or Ofodua, with pH above 6.0. However, Adim irrigation water is still considered suitable but has to be strictly checked before it goes down to 3.5 which padi cannot tolerate due to sulphur accumulation leading to reduced yield (Koli 1983; Pol prasert, 1983) [13].

Conclusion

The results from these studies have shown that irrigation waters in the four study areas have good supply of N, K, Ca and Mg with low conductivity required by the plant. The detrimental effect of effluent at Adim location resulting to sulphur and chlorine loading and drift to irrigation water could lead to sulphate and chloride accumulation and could affect rice growth in the area, if the source of the sulphur and chlorine are not checked. However, the soils have opportunities for rice production with good management.

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