Paddy Water Environ (2008) 6:299–307
DOI 10.1007/s10333-008-0123-0

ARTICLE

Evaluation of *sawah* rice management system in an inland valley in southeastern Nigeria. I: Soil chemical properties and rice yield

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Received: 23 June 2007 / Accepted: 9 March 2008 / Published online: 19 March 2008

Abstract Failures in agricultural development in parts of West Africa may have been caused by the inability of the farmers to develop the abundant inland valleys for cultivation of such crops like rice, using appropriate water management systems. An inland valley in southeastern Nigeria was used to evaluate the influence of *sawah* and non-*sawah* water management using inorganic and organic soil amendments on the soil chemical properties and rice grain yield. Soil chemical properties tested were soil organic carbon, total nitrogen, pH, exchangeable K^+, Ca^{2+} and Mg^{2+}. Others were CEC, percent base saturation and exchangeable acidity while the grain yield of rice was also measured. The soils are loose, low in pH and poor in plant nutrient elements. In spite of that, the *sawah*-managed system was able to improve the pH of the soil by raising it slightly both in the first and second year of planting. Generally, essential plant nutrients such as exchangeable K^+, Ca^{2+} and Mg^{2+}, including fertility index like the CEC, were improved within *sawah* management within the period. Also, rice grain yield increased significantly (5.62 and 6.25 tons/ha in the first year and 5.32 and 6.53 tons/ha in the second year for non-*sawah* and *sawah*, respectively) with *sawah* system such that about 11 and 23% yield increases were obtained in *sawah* over the non-*sawah* in the two years, respectively. Although organic carbon can be used to explain the variation in total grain yield in the first year, it was the CEC that explained the total grain yield in the second year. The study revealed the superiority of *sawah* over non-*sawah* in the production of lowland rice in an inland valley in southeastern Nigeria.

Keywords Rice grain · *Sawah* · Plant nutrient · Chemical properties · Southeasthern Nigeria · Rice yield

Introduction

It has been shown that one of the reasons for failures in green revolutions in West Africa, in spite of its success in Asia, is the inability to develop the abundant lowland valleys for agriculture (Wakatsuki and Masunaga 2005). According to them, environmentally creative technology, or ecological engineering technology, such as *sawah* farming, is not traditionally practiced in sub-Saharan Africa. UNEP/ISRIC (1991) and UNEP (1997) showed that, in sub-Saharan Africa, agriculture is mostly upland cultivation by traditional shifting cultivation systems even under rapid population growth and massive deforestation. This is against the vast lowland areas that are grossly under-utilized.

The term *sawah* refers to a leveled rice field surrounded by bunds with inlet and outlet connections to irrigation and drainage canals. It originated from Malayo-Indonesian term ‘*paddi*,’ which means rice plants. However, the term ‘paddy’ refers to rice grain with husks in the whole of West Africa. Therefore, the paddy field is almost equivalent to the *sawah* for the Asian scientist and to avoid confusion Wakatsuki et al. (2005) used the term *sawah* to distinguish rice grain with husk, rice field and rice plant. *Sawah*, then according to Wakatsuki and Masunaga (2005), is a multifunctional constructed wetland, which is the prerequisite for realizing the objectives of the green revolution as well as

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maintaining a sustainable ecological environment. This kind of farming system is not common in West Africa and especially in southeastern Nigeria, which traditionally are used to mounds and ridges construction for root crop production. Incidentally, rice cultivation is becoming popular with farmers in areas with hydromorphic soil properties.

Achieving high yield in most West African ecology is difficult without soil amendment, as the soils are highly leached, porous and low in essential plant nutrient (Enwezor et al. 1981; Igwe et al. 1995). In some West African ecology, some researchers (Hirose and Wakatsuki 1997; Buri et al. 2000) have observed low nutrient content of the soils. Fashola et al. (2002) noted that poor water management and high nitrogen losses due to high temperature, leaching and runoff are some of the key problems faced by rice farmers under rainfed inland valley systems. They remarked that the use of fertilizers among farmers in West Africa is low, probably due to socio–economic factors. In a green house study using an Ultisol from southeastern Nigeria, Mbagwu (1985) identified rice shavings (husks) and poultry manure, which are readily available, as having the potential to improve maize yields substantially when compared with inorganic fertilizer containing N, P, K and Mg.

In southeastern Nigeria, there have been studies on the use of organic amendments in the improvement of soil chemical properties and crop yields (Agbim 1985; Mbagwu 1985, 1992; Nnabude and Mbagwu 2001), but none has dwelt on the interaction of these soil amendments with water management systems to improve soil properties under rice *sawah* management system. The objectives of the study, therefore, were to determine (1) the effect of *sawah* and non-*sawah* water managements on the chemical properties of the soil and (2) the effects of these management systems on the rice grain yield.

Materials and methods

Site description

The experiment was conducted on the floodplain of Ivo River in Ishiagu, Ebonyi State, Nigeria, at the experimental site of Federal College of Agriculture. It is located on longitude 8°03′E and latitude 6°25′N. The annual rainfall for the area is 1,350 mm, spread from April to October with average air temperature being 29°C. The underlying geological material is Shale formation with sand intrusions locally classified as the ‘Asu River’ group. The site is within the derived savanna vegetation zone with grassland and tree combinations. The soil is described as Aeric Tropoaquent (USDA 1998) or Gleyic Cambisol (FAO 1988). They are sandy loam with moderate soil organic carbon (OC) content on the topsoil, low in pH and low cation exchange capacity (CEC). Soils are mainly used for rain-fed rice cultivation during the rains and vegetable production as the rain recedes.

Field method

The field, which was under fallow for more than 5 years, was disk-ploughed and disk-harrowed to a depth of about 20 cm before puddling and treatments. Prior to ploughing, composite soil sample was taken to characterize the soils (Table 1). The plot was divided into two portions, one part for *sawah* and the second part for non-*sawah* water management. In the non-*sawah*-managed field, there was no defined water management in the field. Water was allowed to flow in and out as it comes, but in the *sawah* field, water was controlled and maintained to an approximate level of between 5 and 10 cm from 2 weeks after transplanting to the stage of ripening of the grains (Fig. 1). In each of the plots, the following treatments, arranged as a Split-Plot on a Randomized Complete Block Design (RCBD), were used:

I	F	NPK fertilizer (20:10:10). Locally recommended rate for rice
II	PD	Poultry droppings
III	RD	Rice husk dust
IV	RD + PD	Rice husk dust + poultry droppings
V	PD + F	Poultry droppings + NPK fertilizer
VI	RD + F	Rice husk dust + NPK fertilizer
VII	F + PD + RD	NPK fertilizer + poultry droppings + rice husk dust
VIII	CT	Control (no soil amendment)

Each treatment was replicated three times and each plot was 6 m × 2.5 m. The NPK fertilizer consisted of 400 kg/ha as compound fertilizer, poultry dropping was applied at the rate of 5 tons/ha and rice husk dust was applied at 10 tons/ha. The RD on decomposition is widely applied by local farmers as source of plant nutrient. The nutrient contents of these organic amendments were determined (Table 2). The mature PD and RD were spread on the plots that received them and incorporated manually into the top 20 cm soil depth 2 weeks before planting. All amendments were applied only in 2004, and their residual effect was measured in 2005. The same plots and replications were maintained for the two years.

The test crop was a high-yielding rice variety *Oryza sativa* var. Tox 3108. This cultivar is widely used by farmers in the area. This was first planted in a nursery field and later transplanted to the main fields after 4 weeks in nursery. At maturity, rice grains were harvested, dried and

Table 1 Some properties of the topsoil (0–20 cm) before ploughing and amendment

Soil property	Value
Clay %	10
Silt %	21
Total sand %	69
Textural class	SL
Organic Carbon % (C)	1.61
Total Nitrogen % (N)	0.091
C/N ratio	18
pH (H_2O)	5.2
Exchangeable bases (cmol/kg)	
Sodium	0.35
Potassium (K)	0.11
Calcium (Ca)	3.0
Magnesium (Mg)	1.6
Cation exchange capacity (CEC)	5.06
Exchangeable acidity (EA)	1.8
Available P (mg/kg)	22

Table 2 Nutrient concentrations (%) in the amendments

Property	Amendment	
	Poultry dropping (PD)	Rice husk dust (RD)
P	2.55	0.49
Ca	14.4	0.36
Mg	1.2	0.38
Na	0.34	0.22
K	0.48	0.11
C	16.52	33.72
N	2.1	0.7
C:N	7.9	48.2
C:P	6.5	68.8

yield computed at 90% dry matter content. This was done for the two years (2004 and 2005). At the end of each harvest, soil samples were collected from each replicate of every plot for chemical analyses.

Laboratory methods

Soil samples were air-dried and sieved with 2-mm sieve. Soil fractions under 2 mm from each of the replicates were then analyzed using the following methods; Particle size distribution of less than 2-mm fine earth fractions was measured by the hydrometer method as described by Gee and Bauder (1986). Soil pH was measured in a 1:2.5 soil: 0.1 M KCl suspensions. The soil OC was determined by the Walkley and Black method described by Nelson and Sommers (1982). Exchangeable cations were determined by the method of Thomas (1982). CEC was determined by the method described by Rhoades (1982), while exchangeable acidity (EA) was measured using the method of McLean (1982). Available phosphorus was measured by the Bray II method (Bray and Kurtz 1945).

Data analysis

Data analysis was performed by the analyses of variance (ANOVA) test, and statistical differences among treatment means were estimated by the Duncan's multiple range

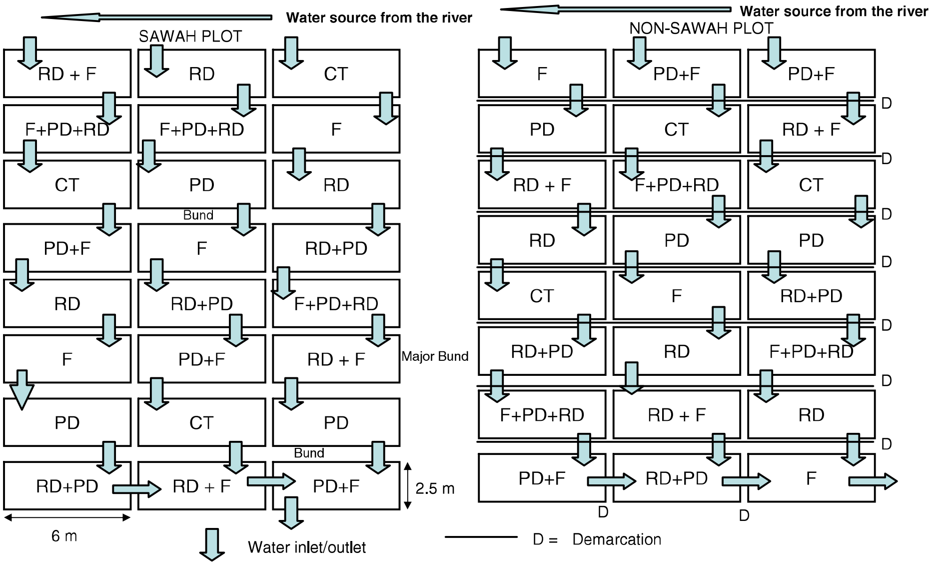

Fig. 1 Field experimental layout for the study

Spaces between plots and replications are bunds to maintain water levels in sawah plot while they are mere demarcations in non-sawah plots tests. Correlation and regression analysis were used to determine the relationships among soil properties and rice grain yield using the SPSS.10 on Windows computer package.

Results and discussion

Effect of *sawah* and amendments on soil OC, total nitrogen and pH

The influence of the *sawah* management systems and the soil amendments on the soil OC, total nitrogen and soil pH are shown (Table 3). The amendments significantly affected the soil OC in both *sawah* and non-*sawah* system in the first year of amendment as well as in the second year. Incidentally, there was no significant difference between the non-*sawah* and *sawah* management in both years. While the average value of OC was lower in the first year in the *sawah*-managed system, it was more than the non-*sawah* managed system in the second year. This trend shows that while in the first year the OC was not completely decomposed and mineralized in the *sawah* system, it was, however, slowly mineralized and released in the *sawah* system of second year. Although in upland managed maize, Mbagwu (1992) observed that there was a decrease in the amount of OC in the second year, in our study we obtained a relative increase in the OC values in the second year. This may be attributed to what Hirose and Wakatsuki (2002) indicated to relate to the hypothesis of adjacent upland debris and materials feeding the inland valleys with a corresponding addition of OC in the *sawah*-managed system.

Soil total nitrogen for the two water management systems differed significantly with amendments, but not with *sawah* managements. However, total nitrogen was nominally higher in the *sawah*-managed system in the first year than the non-*sawah*-managed system. There was no significant difference in the total nitrogen levels in the second year. These results may have been caused by environmentally related factors such as heavy rains often falling during the growing season, resulting in leaching. Also high temperature may have also resulted in the volatile loss of the nitrogen. Fashola et al. (2002) observed that runoff and leaching could greatly reduce the level of nitrogen in rainfed rice field.

The pH condition for the soils differed significantly in both amendments and *sawah* managements in the two years. In the two years, the *sawah* water-managed system recorded an increase in the pH significantly (Table 3). It shows that with proper and well-managed water in inland valley rice field, pH will improve, thus enabling good soil environment for plant nutrition.

Table 3 Effect of *sawah* system and amendments on soil organic carbon, nitrogen and pH on 0–20 cm topsoil

Amendment	Non-*sawah*			*Sawah*		
	OC %	N %	pH	OC %	N %	pH
First year						
F	0.67	0.074	4.8	0.45	0.071	5.2
PD	0.49	0.069	4.9	0.43	0.076	5.1
RD	0.83	0.047	5.0	0.62	0.070	5.1
RD + PD	0.55	0.062	5.1	0.63	0.061	4.8
PD + F	0.49	0.070	5.2	0.48	0.051	5.2
RD + F	0.76	0.062	4.8	0.62	0.082	5.1
F + PD + RD	0.76	0.065	4.9	0.46	0.070	5.2
CT	0.76	0.055	4.9	0.47	0.057	5.1
Mean	0.66	0.063	5.0	0.52	0.067	5.2
LSD (0.05)	0.18	0.012	0.22	0.18	0.012	0.22
LSD (0.05) Non-*sawah* × *sawah* OC				NS		
Non-*sawah* × *sawah* N				NS		
Non-*sawah* × *sawah* pH				0.13		
Second year						
F	0.68	0.056	4.5	0.54	0.065	4.8
PD	0.72	0.061	4.4	0.92	0.056	4.6
RD	0.72	0.065	4.4	0.91	0.056	4.8
RD + PD	0.72	0.051	4.4	0.87	0.047	4.9
PD + F	0.66	0.045	4.5	0.76	0.065	4.7
RD + F	1.01	0.056	4.5	0.86	0.056	5.0
F + PD + RD	0.69	0.061	4.4	0.65	0.057	4.7
CT	0.67	0.051	4.7	1.07	0.043	4.8
Mean	0.73	0.056	4.4	0.82	0.056	4.8
LSD (0.05)	0.22	0.006	0.20	0.22	0.006	0.20
LSD (0.05) Non-*sawah* × *sawah* OC				NS		
Non-*sawah* × *sawah* N				NS		
Non-*sawah* × *sawah* pH				0.07		

NS nonsignificant

Effect of *sawah* and amendments on exchangeable potassium, calcium and magnesium

Exchangeable potassium increased significantly with *sawah*-managed system in the first and second year of study (Table 4). In the first year, it increased from 0.13 cmol/kg in non-*sawah* to 0.15 cmol/kg in the *sawah*-managed system. The same trend was also maintained in the second year with a significant increase from 0.14 cmol/kg in non-*sawah* to 0.19 cmol in *sawah*-managed system. Generally, in the two years, *sawah*-managed system contributed to the increase of exchangeable K in the soils.

Also the exchangeable Ca was higher in the *sawah* system than in the non-*sawah* system in the first and second year (Table 4). Significantly, higher values of exchangeable Ca were always obtained in the *sawah*-managed plots. At the same time, Ca values with the amendments significantly differed among the amendments with the least in PD + F in non-*sawah* and control of the first year. Lowest values of Ca were obtained in RD and RD + F in the non-*sawah*, but in CT of *sawah* of the second year.

In the first year, the values for exchangeable magnesium varied significantly. It changed from 1.11 cmol/kg in the non-*sawah* to 1.12 cmol/kg in the *sawah* (Table 4). Also, the amendments significantly affected the release of the exchangeable Mg. In the second year, there was a significant increase in the value of exchangeable Mg from 1.02 cmol/kg in the non-*sawah* to 1.19 cmol/kg in the *sawah*-managed system. In general terms, it will be concluded that well or better managed water system, as in the *sawah* in the present study, improved nutrient supply, reserve and release of their exchangeable forms, which are very essential in plant nutrition. Witt et al. (2005) showed that the management of these nutrients should be offered greater attention if appreciable yield was to be obtained especially in intensive irrigated lowland rice systems. These soils are poor in their native availability of these nutrients as expressed by some researchers (Unamba-Oparah 1985; Mbagwu 1989). Therefore, *sawah* may help in the solution of low nutrient levels in the soil.

Effect of *sawah* and amendments on CEC, base saturation and EA

In most cases, the different soil amendments improved the soil CEC both in the non-*sawah* and in the *sawah*-managed system in the first year of planting (Table 5). The best improvement over the control was obtained in the *sawah*-managed system. Also, there was a significant improvement in the CEC (3.45 cmol/kg of the non-*sawah*-managed to 3.73 cmol/kg) in the *sawah*-managed system in the first year. In the second year of planting, the trend in the first year was continued. There was a better improvement in the

Table 4 Effect of *sawah* system and amendments on exchangeable potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) on 0–20 cm topsoil

Amendment	Non-*sawah*			*Sawah*		
	K^+ (cmol/kg)	Ca^{2+} (cmol/kg)	Mg^{2+} (cmol/kg)	K^+ (cmol/kg)	Ca^{2+} (cmol/kg)	Mg^{2+} (cmol/kg)
First year						
F	0.17	1.80	1.27	0.22	1.87	1.47
PD	0.20	1.93	1.27	0.21	2.53	1.67
RD	0.13	1.73	1.07	0.15	2.00	0.93
RD + PD	0.11	2.00	1.00	0.12	2.20	1.33
PD + F	0.08	1.53	1.13	0.11	1.73	1.13
RD + F	0.013	1.87	1.00	0.19	2.13	1.13
F + PD + RD	0.11	1.87	1.00	0.11	1.93	1.20
CT	0.13	1.73	1.13	0.09	1.47	0.93
Mean	0.13	1.81	1.11	0.15	1.98	1.12
LSD (0.05)	0.03	0.36	0.30	0.03	0.36	0.30
LSD (0.05) Non-*sawah* × *sawah* K^+				0.018		
Non-*sawah* × *sawah* Ca^{2+}				0.04		
Non-*sawah* × *sawah* Mg^{2+}				0.014		
Second year						
F	0.18	1.80	1.07	0.21	1.93	1.20
PD	0.09	1.67	0.93	0.20	2.27	1.20
RD	0.15	1.53	1.00	0.17	1.93	0.73
RD + PD	0.15	1.60	0.73	0.30	2.80	2.20
PD + F	0.18	1.87	1.33	0.16	1.87	1.27
RD + F	0.12	1.53	1.20	0.20	2.07	0.93
F + PD + RD	0.17	1.67	0.87	0.16	2.33	1.13
CT	0.11	1.73	1.00	0.10	1.47	0.87
Mean	0.14	1.68	1.02	0.19	2.08	1.19
LSD (0.05)	0.04	NS	NS	0.04	NS	NS
LSD (0.05) Non-*sawah* × *sawah* K^+				0.02		
Non-*sawah* × *sawah* Ca^{2+}				0.10		
Non-*sawah* × *sawah* Mg^{2+}				0.16		

NS nonsignificant

Table 5 Effect of *sawah* system and amendments on cation exchange capacity, percent base saturation and exchangeable acidity on 0–20 cm topsoil

Amendment	Non-*sawah*			*Sawah*		
	CEC (cmol/kg)	BSAT (%)	EA (cmol/kg)	CEC (cmol/kg)	BSAT (%)	EA (cmol/kg)
First year						
F	3.60	44.3	1.87	3.39	49.9	1.67
PD	3.79	49.2	1.93	4.82	66.9	1.53
RD	3.49	44.7	1.40	3.42	55.2	1.87
RD + PD	3.49	45.9	1.67	4.06	50.1	1.93
PD + F	3.09	56.8	2.00	3.37	49.1	1.93
RD + F	3.38	57.8	2.27	3.79	58.8	2.27
F + PD + RD	3.36	49.0	2.13	3.64	47.2	1.87
CT	3.41	39.8	2.20	2.84	41.9	2.27
Mean	3.45	48.4	1.93	3.73	52.4	1.92
LSD (0.05)	0.56	14.2	0.44	0.56	14.2	0.44
LSD (0.05) Non-*sawah* × *sawah* CEC				0.03		
Non-*sawah* × *sawah* BSAT				NS		
Non-*sawah* × *sawah* EA				NS		
Second year						
F	3.42	32.2	1.80	3.72	50.5	1.73
PD	3.03	43.6	1.93	4.06	56.8	1.70
RD	3.09	40.3	1.87	3.26	52.5	1.87
RD + PD	2.88	54.4	2.20	5.87	50.7	1.87
PD + F	3.75	58.4	2.00	3.71	48.6	1.18
RD + F	3.23	55.3	2.87	5.56	53.3	2.87
F + PD + RD	3.12	51.5	2.13	4.03	49.7	1.97
CT	3.21	35.3	2.00	2.79	37.7	1.93
Mean	3.22	46.4	2.10	4.13	50.0	1.89
LSD (0.05)	0.96	7.4	0.80	0.96	7.4	0.80
LSD (0.05) Non-*sawah* × *sawah* CEC				0.25		
Non-*sawah* × *sawah* N BSAT				2.82		
Non-*sawah* × *sawah* EA				NS		

NS nonsignificant, *CEC* cation exchange capacity, *BSAT* percent base saturation, *EA* exchangeable acidity

CEC with amendments in the *sawah* system than in the non-*sawah* system of management. Overall, the CEC improved significantly from 3.22 cmol/kg in the non-*sawah* to 4.13 in the *sawah* system.

Both the percent base saturation and EA did not differ significantly with the non-*sawah* and *sawah* management in the first year of planting (Table 5). However, a line of trend showed that the percent base saturation increased in the *sawah*-managed system. Also, amendments improved the percentage base saturation significantly both in the non-*sawah* and *sawah* systems during the first year of planting. During the second year of planting, percent base saturation improved significantly with amendment in the *sawah*-managed plots and significantly increased from 46.4% in the non-*sawah* plots to 50% in the *sawah*-managed plots. This thus further confirmed the superiority of the *sawah* management over the non-*sawah* management in the generation, release and reserve of soil plant available nutrients. The superiority of *sawah* over non-*sawah* for a profitable rice production in terms of nutrient reserve has earlier been highlighted (Wakatsuki et al. 2002; Ganawa et al. 2003; Wakatsuki and Masunaga 2005). Apart from EA, which differed significantly with amendments in the second year of planting, there was no significant difference between the non-*sawah* and *sawah* management. However, the overall mean values went down in the *sawah*-managed plots in the second year of planting. The lowering of the EA was considered to be a nice attribute for the *sawah* system.

Effect of *sawah* and amendments on rice grain yield

Table 6 presents the effects of different water managements (non-*sawah* and *sawah*) on the grain yield of rice. Generally, there were very significant improvements in the rice yield in the amendments over the non-amended (CT) plots. In the first year of planting, the rice grain yield

Table 6 Effect of *sawah* system and amendments on rice grain yield (tons/ha)

Amendment	First year		Second year	
	Non-*sawah*	*Sawah*	Non-*sawah*	*Sawah*
F	6.18	7.11	5.30	6.28
PD	6.37	6.56	5.41	6.52
RD	5.26	6.56	6.07	6.00
RD + PD	5.45	5.96	4.81	7.96
PD + F	6.44	6.65	5.55	7.30
RD + F	5.31	6.11	6.15	6.45
F + PD + RD	5.37	5.78	5.02	7.06
CT	4.59	5.23	4.26	4.68
Mean	5.62	6.25	5.32	6.53
LSD (0.050)	0.32	0.32	0.80	0.80
Non-*sawah* × *sawah*		0.14		0.50

Table 7 Correlation coefficients between rice grain yield and some soil chemical properties

Independent variables	Correlation coefficients (*r*)			
	First year		Second year	
	Non-*sawah*	*Sawah*	Non-*sawah*	*Sawah*
Organic carbon %	−0.75*	0.28	−0.47	−0.01
Nitrogen %	0.81*	−0.12	0.57	0.45
pH	0.24	0.22	0.38	0.31
CEC (cmol/kg)	0.12	0.45	0.19	0.66*
Base saturation %	0.45	0.38	0.38	0.07
Exchangeable acidity (cmol/kg)	−0.13	−0.68*	0.32	−0.13
Exchangeable Mg^{2+} (cmol/kg)	0.59	0.48	0.60	0.84*
Exchangeable Ca^{2+} (cmol/kg)	−0.15	0.32	−0.37	0.64*
Exchangeable K^+ (cmol/kg)	0.25	0.70*	0.06	0.34

* Significant at $P > 0.05$

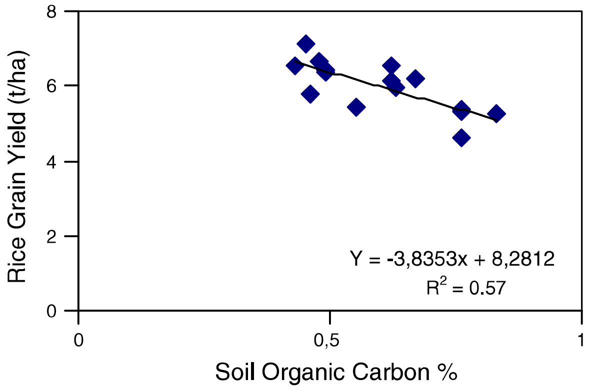

Fig. 2 Relationships between organic carbon and rice grain yield in the first year

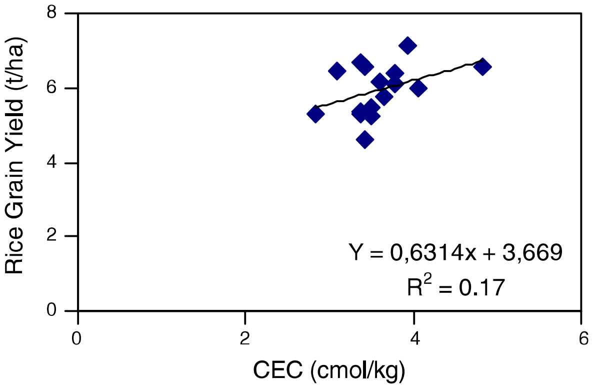

Fig. 3 Relationships between CEC and rice grain yield in the first year

increased significantly from 5.62 tons/ha in the non-*sawah*-managed plots to 6.25 tons/ha in the *sawah*-managed plots. Also, in the second year of planting, yield increased significantly from 5.32 tons/ha in *sawah* plots to 6.53 tons/ha in the *sawah*-managed plots. Thus, there was about 11% increase in yield in *sawah* system in the first year and a 23% increase in yield in the second year of planting. It was shown here that the crop responded differently to the soil amendments, whether in *sawah* or in the non-*sawah* plots. However, the underlying thing was that, in both years, more grain yield was obtained in *sawah* than in non-*sawah* plots. Ofori et al. (2005) showed that high yield responded to good water management conditions in the *sawah* system with optimum input level.

In the non-*sawah*-managed plots in the first year of planting, rice grain yield negatively correlated significantly with OC ($r = -0.75$*), but positively correlated with total nitrogen ($r = 0.81$*) (Table 7). The reason for this may be that the higher OC was tied down in the event of high total nitrogen reducing mineralization and reduction in the release of nutrients. In the *sawah*-managed system, where as rice grain yield negatively correlated with EA, it positively correlated significantly with exchangeable K^+. During the second year of planting, rice grain yield positively correlated significantly with CEC, exchangeable Mg^{2+} and exchangeable Ca^{2+} (Table 7). This observation has further confirmed the role *sawah* management plays in the generation of these nutrients for higher yield of rice grain. Again, in the first year of planting, the variation in rice grain yield was explained by 57% as against the 17% explained by CEC (Figs. 2, 3).This situation was reversed in the second year when OC only explained as low as 2%

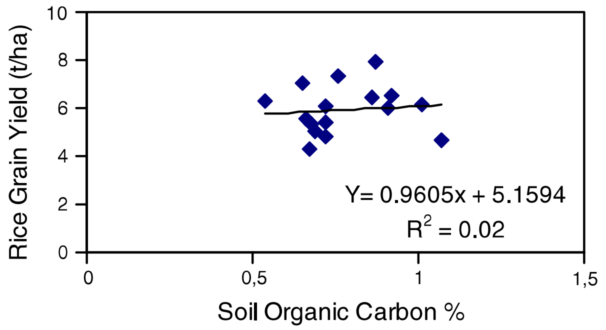

Fig. 4 Relationships between organic carbon and rice grain yield in the second year

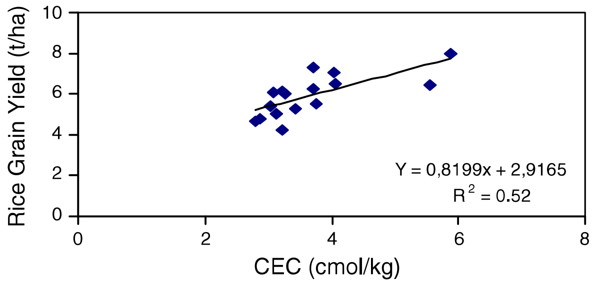

Fig. 5 Relationships between CEC and rice grain yield in the second year

(Fig. 4) of variation in yield, while CEC explained 52% of the variation (Fig. 5). These show that in the first year the effect of the OC was very well felt, while in the second year it was the already mineralized OC and the nutrient reserve that explained the grain yield obtained.

Conclusion

From the present study, the following conclusions can be made. The soils are loose, low in pH and poor in plant nutrient elements. In spite of that, the *sawah*-managed system was able to improve the pH of the soil by raising the pH slightly both in the first and second year of planting. Generally, essential plant nutrients such as exchangeable K^+, Ca^{2+} and Mg^{2+} including fertility index like the CEC were improved upon in *sawah* management within the period.

Also, rice grain yield increased significantly with *sawah* system such that about 11 and 23% yield increases were obtained in *sawah* over non-*sawah* in the two years, respectively. Although OC can be used to explain the variation in total grain yield in the first year, it was the CEC that explained the total grain yield in the second year. The study revealed the superiority of *sawah* over non-*sawah* in the production of lowland rice in an inland valley in southeastern Nigeria.

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