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Sawah Rice System, a Technology for Sustainable Rice Production and Soil Chemical Properties Improvement in Ebonyi State of Southeastern Nigeria

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Abstract: The soils in Ebonyi State agro-ecological zones of southeastern Nigeria are plagued with characteristics that impede optimal crop production. Failures in agricultural development in this part of southeastern Nigeria may have been caused by the inability of the farmers to develop the abundant inland valleys for such crops like rice using appropriate water management systems. In order to arrest the declining productivity of the inland valley soils in these zones, four different organic sources (Rice husk; Rice husk ash; Poultry droppings at 10 t/ha and NPK 20:10:10 at 400 kg/ha) were used in four different sawah environments including farmers environment (Complete sawah; Incomplete sawah; Partial sawah and farmer's environment) in two inland valleys in southeastern Nigeria to evaluate their effects on some soil properties and rice grain yield. *Sawah* is generally described as a controlled water management in the field where the soil is expected to be puddle, leveled and bunded in order to impound water provided by rain water or by rise in the level of a river in an inland valley. The field layout was Split-plot in a randomized complete block design (RCBD) in which the five treatments (including the control) were replicated three times within the four sawah environments including the farmer's field. The field was demarcated into four main plots with five sub-plots in each using 0.6m raised bunds except in the main plot used as farmer's field. The four main plots were prepared and managed according to specifications of the study. The bunds have inlet and outlet channels through which water is introduced into the field from a water source and excess drain from the field, respectively. The test crop was a high yielding rice variety (*Oryza sativa var. FARO 52/WITA 4*). The rice seedlings were transplanted at the age of three weeks after nursery. Soil properties tested were soil organic carbon, total nitrogen, pH, CEC, EA and Base saturation, while the grain yield of rice was also measured. The results showed that soil pH, OC and TN were statistically improved within sawah managed environment in both locations. The amendments also improved the pH, TN, CEC and base saturation during the period. Also rice grain yield was statistically increased by both sawah managed environments and the soil amendments, with complete sawah environment amended with poultry droppings giving the highest significant increase in the yield of 7.5 tons per hectare.

Key words: Sawah environment · Soil properties · Rice grain yield · Soil amendment

INTRODUCTION

Increasing food production both to meet in-country requirements and to help the world overcome food crisis is one major issue facing Nigeria today. In spite of the potentials of Nigeria inland valleys especially the Southeast for Agricultural use, these areas are yet to be exploited fully.

Poor soil fertility and inefficient weed and water control are the major constraints to proper utilization of these inland valleys for sustainable rice-based cropping. The soils of Southeastern Nigeria particularly,

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Ebonyi State is low in fertility. The soils have been noted to be acidic, low in organic matter status, cation exchange capacity and other essential nutrients [1-4]. In Southeastern Nigeria, there have been studies on the use of organic and inorganic amendments in the improvement of the soil chemical properties and crop yields [5-8], but none has dwelt on the interaction of these soil amendments with water management systems to improve soil properties under rice *sawah* management system.

Rice production is the major cropping operation in both Ebonyi Central and South agro-ecological zones of the Southeastern Nigeria. The crop is poised with the problem of realizing production owing to the soil fertility, weed and water management problems.

Determining appropriate fertility, weed and water management practices could lead to improved and sustainable crop yields in these areas. An African adaptive *sawah* lowland farming with small scale irrigation scheme for integrated watershed management will be the most promising strategy to tackle these problems and restore the degraded inland valleys in these areas for increased and sustainable food production [9]. With the introduction of the sawah rice production technology to Nigeria in the late 1990s and its high compatibility with our inland valleys, the place of these land resources in our agricultural development in this Southeastern Nigeria and realization of green revolution is increasingly becoming clearer [10]. However, most farmers do not know much about the rudiments or fundamentals of this technology. *Sawah* merely involved bunding, puddling and leveling, with provisions for inlet and outlet channels on the bunds for irrigation and drainage. Construction of canals which could be interceptive canal (point of collection of flowing water from adjacent uplands) or the canal(s) linked to water source(s) to the field (rivers, dams or streams) are also involved in this technology. Consequently, the benefit of the bunding is that it ensures that water is regulated in the field at all time during the growing period of the crop. It is therefore important to note that the rice field environment determines good management of fertility, weed and water. Andriesse [11] noted that in order to realize and sustain the potential benefits accruable from cultivating the inland valleys of West Africa, much of the research effort in these land resources is geared towards alleviating productivity constraints.

The study aimed at bridging the gaps in knowledge of appropriate inland valleys and *sawah* technology development in Nigerian lowlands among the farmers. It also aimed at assessing different soil amendments using different ploughing (environments) to *sawah* technology for appropriate fertility, weed and water management in inland valleys of Southeastern Nigeria.

MATERIALS AND METHODS

Site Description: The study was conducted in 2010 on the floodplain of Ivo River in Akaeze, Ebonyi South and Oyolo River in Igweledoha, Ebonyi Central, both in Ebonyi State of Southeastern Nigeria. Akaeze lies at approximately latitude 05°56' N and longitude 07°41' E. The annual rainfall for the is 1,350 mm, spread from April to October with average air temperature of 29°C. Igweledoha on the other hand, lies within latitude 06°08' 40" N and longitude 08°06' 35" E. The two sites are within the derived savanna vegetation zone with grassland and tree combinations. The soils are described as Aeric Tropoaquent [12] or Gleyic Cambisol [13]. The soils have 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 in each location was divided into four different main plots where the four rice growing environments were located. Bulk (composite) sample was collected at 0-20 cm soil depth in the 2 locations for initial soil characteristics. Out of the four main plots, three were demarcated with a 0.6 m raised bunds. In these plots, water was controlled and maintained to an approximate level of between 5 cm to 10 cm from 2 weeks after transplanting to the stage of ripening of the grains, while in other plot without bunds which represent the traditional field; water was allowed to flow in and out as it comes, as described below:

The four rice growing environments which represented the 4 main plots include;

- Main plot I; Complete sawah: bunded, puddle and leveled rice field (CS)
- Main plot II; Incomplete sawah: bunded and puddle with minimum leveling rice field (ICS)
- Main plot III; Partial sawah: bunded, no puddling and leveling rice field (PS)
- Main plot IV; Farmers environment: no bunding, puddling and leveling rice field (FE)

Table 1: Some properties of the topsoil of the experimental plots (0-20 cm) before tilling and amendment

Soil properties	Value Location 2 (Igweledoha)	Location 1 (Akaeze)
Clay %	17	10
Silt %	39	21
Total sand %	44	69
Textural class	L	SL
Organic matter %	1.67	2.64
Organic carbon % (OC)	0.97	1.61
Total nitrogen % (N)	0.056	0.091
pH (H_20)	3.7	3.6
pH (KCl)	2.6	3.0
Exchangeable bases (cmolkg^{-1})		
Sodium (Na)	0.27	0.15
Potassium (K)	0.13	0.04
Calcium (Ca)	1.6	1.0
Magnesium (Mg)	1.0	0.6
Cation exchange capacity (CEC)	11.2	5.6
Exchangeable acidity (EA)	2.0	3.2
Available phosphorous (mg/kg)	7.83	4.20
Base saturation (BS)	26.79	24.70

L = Loamy soil; SL = Sandy-loam soil

Table 2: Nutrient compositions (%) in the amendments

	Amendment		
	Poultry dropping (PD)	Rice husk (RH)	Rice husk ash (RHA)
OC	16.52	33.75	3.89
N	2.1	0.7	0.056
Na	0.34	0.22	0.33
K	0.48	0.11	1.77
Ca	14.4	0.36	1.4
Mg	1.2	0.38	5.0
P	2.55	0.49	11.94
C:N	7.87	48.21	6.71

OC = Organic carbon; N = Nitrogen; Na = Sodium; K = Potassium; Ca = Calcium; Mg = Magnesium; P = Phosphorous; C:N = Carbon: Nitrogen ratio

The complete and incomplete sawah field environments were tilled with power-tiller according to the specification of environment; the rest of other environments were manually tilled using the specifications stated above.

This was followed by the demarcation of each of the main plots into five subplots with other raised bunds, which were treated with soil amendments. In each of the sub-plots, the following treatments were arranged as a Split-Plot in a randomized complete block design (RCBD).

- I PD Poultry droppings @ 10 ton/ha
- II F NPK fertilizer (20:10:10) @ 400 kg/ha recommended rate for rice in the zones
- III RHA Rice husk ash @ 10 ton/ha obtain within the vicinity
- IV RH Rice husk @ 10ton/ha, also obtained within the vicinity
- V CT Control (no soil amendment)

Each treatment was replicated three times and each sub-plot was 6 m x 6 m. The PD, RHA and RH were spread on the plots that received them and incorporated manually into the top 20 cm soil depth 2 weeks before transplanting. The nutrient contents of these organic amendments were determined (Table 2).

The test crop was high-tillering rice variety *Oryza sativa var. FARO 52 (WITA 4)*. The rice seeds were first raised in the nursery and later transplanted to the main field after 3 weeks in nursery. At maturity, rice grains were harvested, dried and yield computed at 90% dry matter content. At the end of harvest, soil samples were collected from each replicate of every plot from each of the location for chemical analyses.

Laboratory Methods: Soil samples were air-dried and sieved with 2 mm sieve. Soil fractions less than 2 mm from individual samples 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 [14]. 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 [15]. Total nitrogen was determined by semi-micro kjeldahl digestion method using sulphuric acid and $CuSO_4$ and Na_2SO_4 catalyst mixture [16]. Exchangeable cations were determined by the method of Thomas [17]. CEC was determined by the method described by Rhoades [18], while exchangeable acidity (EA) was measured using the method of McLean [19]. Base saturation was determined by calculation as the percentage ratio of total exchangeable bases to effective cation exchange capacity, using the procedure outlined in Tropical Soil Biology and Fertility Manual [20].

Data Analysis: Data analysis was performed using GENSTAT 3 7.2 Edition.

Significant treatment means was separated and compared using Least Significant Difference (LSD) and all inferences were made at 1% and 5% Levels of probability.

RESULTS AND DISCUSSION

Effect of *sawah* field growing environment and soil amendments on the soil pH, organic carbon and nitrogen on 0-20 cm topsoil

The result in Table 3 indicated that soil pH statistically differed (P< 0.05) among the sawah field environments in the two locations with complete sawah field environment having the highest value of 4.91, while the lowest was recorded in the farmer's field environment with 4.71 in Akaeze and 4.87-4.74 in complete and farmer's fields, respectively at Igweledoha location. The pH condition for the soil also showed significant difference among the amendments at (P< 0.001) in both sites with RHA in complete sawah field having the highest values. This results agreed with Nwite *et al.,* [21-22, 9], that proper and well-managed water in inland valley rice field and also use of ash materials, pH will improve, thus enabling good soil environment for plant nutrition.

The amendments significantly (P< 0.001) affected the soil OC in the sawah environments in both locations with RH recording the highest values in all the environments.

Table 3: Effect of *sawah* field growing environment and soil amendments on the soil pH, organic carbon and nitrogen on 0-20 cm topsoil

	Sawah Environments											
	Complete			Incomplete			Partial			Farmer's environment		
Amendments	pH	OC %	N %	pH	OC %	N %	pH	OC %	N %	pH	OC %	N %
Akaeze location												
PD	4.9	1.37	0.0887	4.83	1.38	0.098	4.87	1.24	0.084	4.7	1.06	0.0793
NPK	4.9	1.44	0.098	4.83	1.133	0.0887	4.73	1.31	0.0747	4.6	1.06	0.0747
RHA	5.2	1.33	0.084	5.07	1.117	0.0747	4.93	1.06	0.0847	4.8	1	0.07
RH	4.9	1.5	0.098	4.9	1.3	0.07	4.83	1.72	0.0747	4.9	1.13	0.0657
CT	4.67	1.09	0.0653	4.53	0.907	0.0607	4.57	0.7	0.0607	4.5	0.78	0.0513
Mean	4.91	1.344	0.0868	4.83	1.207	0.0784	4.79	1.21	0.0757	4.71	1.01	0.0682
LSD (0.05)	0.11	0.21	0.0134	0.11	0.21	0.0134	0.11	0.21	0.0134	0.11	0.21	0.0134
LSD (0.05) Environments pH		0.088										
LSD (0.05) Environments x Amendments pH	NS											
LSD (0.05) Environments OC		0.164										
LSD (0.05) Environments x Amendments OC	NS											
LSD (0.05) Environments N	NS											
LSD (0.05) Environments x Amendments N		NS										
Igweledoha location												
PD	4.9	0.98	0.084	5	0.99	0.098	4.9	1.15	0.085	4.8	1.04	0.07
NPK	4.8	1.11	0.084	4.9	1.04	0.103	4.9	0.72	0.079	4.8	1.02	0.061
RHA	5.2	1.23	0.089	5	0.77	0.07	5	1.19	0.081	4.8	0.98	0.065
RH	4.9	1.08	0.11	5	1.32	0.09	4.9	1.12	0.102	4.8	1.18	0.07
CT	4.5	1.06	0.047	4.6	1.24	0.065	4.6	0.95	0.056	4.5	0.91	0.051
Mean	4.9	1.09	0.082	4.86	1.08	0.085	4.85	1.03	0.081	4.7	1.03	0.064
LSD (0.05)	0.08	NS	0.011	0.08	NS	0.011	0.08	NS	0.11	0.08	NS	0.11
LSD (0.05) Environments pH	NS											
LSD (0.05) Environments x Amendments pH	NS											
LSD (0.05) Environments OC	NS											
LSD (0.05) Environments x Amendments OC	NS											
LSD (0.05) Environments N	NS											
LSD (0.05) Environments x Amendments N	NS											

PD = poultry dropping; NPK = Nitrogen:phosphorous:potassium; RHA = Rice husk ash; RH = Rice husk; CT = Control; OC = organic carbon; N = Nitrogen

Table 4: Effect of *sawah* field growing environment and soil amendments on the soil CEC, EA and Base saturation (BS) on 0-20 cm topsoil

	Sawah Environments											
	Complete (cmolkg-1) (%)			Incomplete (cmolkg-1) (%)			Partial (cmolkg-1) (%)			Farmer's environment (cmolkg-1) (%)		
Amendments	CEC	EA	BS	CEC	EA	BS	CEC	EA	BS	CEC	EA	BS
Akaeze location												
PD	10.13	2.20	35.2	9.87	2.67	15.4	8.53	3.6	27.5	7.6	3.0	24.8
NPK	8.93	3.33	29.9	6.93	2.8	33.8	9.33	2.8	28.4	7.2	3.07	45.3
RHA	10.53	1.33	31	8.77	1.93	36.3	5.33	2.07	57.3	9.2	2.47	24.3
RH	6.67	2.87	23.3	7.07	4.53	33.6	6.13	2.47	26.9	5.47	3.13	37.9
CT	5.33	3.13	18.3	3.73	4.53	23.7	4.4	4.13	19.2	3.6	4.67	17.1
Mean	8.32	2.57	27.5	7.27	3.29	34.6	6.75	3.01	31.9	6.61	3.27	29.9
LSD (0.05)	2.77	0.74	9.93	2.77	0.74	9.93	2.77	0.74	9.93	2.77	0.74	9.93
LSD (0.05) Environments CEC	NS											
LSD (0.05)Environments x Amendments CEC	NS											
LSD (0.05) Environments EA	NS											
LSD (0.05) Environments x Amendments EA	NS											
LSD (0.05) Environments BS	NS											
LSD (0.05) Environments x Amendments BS	NS											
Igweledoha location												
PD	12.53	3.2	57.43	11.33	3.33	41.06	12.87	3.87	33.07	10.8	3.6	24.39
NPK	12.53	3.67	46.61	11.4	3.6	46.65	11.73	3.93	32.33	10.27	4.07	28.39
RHA	15.07	1.93	54.21	12	2.53	53.77	13.2	2.0	37.76	10.6	3.07	26.42
RH	12.67	3.27	33.71	13.2	3.6	43.43	12.8	3.53	31.89	10.93	3.73	22.08
CT	6.53	4.0	17.85	4.8	4.13	22.05	8.0	4.07	16.34	5.47	5.07	16.9
Mean	11.87	3.21	41.96	10.55	3.44	41.39	11.72	3.48	30.28	9.61	3.91	23.64
LSD (0.05)	1.7	0.41	6.08	1.7	0.41	6.08	1.7	0.41	6.08	1.7	0.41	6.08
LSD (0.05) Environments CEC	1.58											
LSD (0.05)Environments x Amendments CEC	NS											
LSD (0.05) Environments EA	NS											
LSD (0.05) Environments x Amendments EA	NS											
LSD (0.05) Environments BS	12.31											
LSD (0.05) Environments x Amendments BS	15.22											

PD = poultry dropping; NPK = Nitrogen:phosphorous:potassium; RHA = Rice husk ash; RH = Rice husk; CT = Control; CEC = Cation exchange capacity; EA = Exchangeable acidity; BS = Base saturation

The result also indicated that OC was equally significantly improved at ($P< 0.05$) with complete sawah environment giving the highest values in both locations. The result concurs with the findings reported by Rasmussen [23], Hirose and Wakatsuki [24] and Tebrugge *et al.,* [25], crop residues in a soil layer significantly influence soil OC using different ploughing methods and it also relate to adjacent upland debris and materials feeding the inland valleys with a corresponding addition of OC in the sawah-managed system.

Effect of *Sawah* Field Growing Environment and Soil Amendments on the Soil CEC, EA and Base Saturation (BS) on 0-20 cm Topsoil: The results in Table 4 showed that CEC was significantly improved by RHA in most sawah environments. The different soil amendments improved the soil CEC both in Akaeze and Igweledoha locations.

The results also indicated that the soil EA was decreased significantly in complete sawah environment with the application of amendments. The percent BS was also significantly affected by soil amendments in the sawah environments. The overall drop in the mean EA values in the complete sawah environment of the trial was considered to be attributing for the sawah system [9].

On the other hand, the results showed an overall trend of significant ($P< 0.001$) increase in CEC and percent BS in sawah system. With the traditional system of rice farming, these soil properties normally decrease on the course of cropping. These results thus further confirm the superiority of the complete sawah system of rice production. Previous experiments conducted near the present sites to evaluate the effect of the sawah system on soil properties similarly showed the sawah system to be superior to improper or non-sawah system with respect to generation, release and reserve of soil plant available nutrient [21-22].

Other studies elsewhere also upheld the superiority of sawah system over non-sawah system especially in terms of nutrient reserve for a profitable rice production [26-28].

Table 5: Effect of *sawah* field growing environment and soil amendments on the rice grain yield (ton/ha)

	Sawah Environments			
	Complete	Incomplete	Partial	Farmer's environment
Amendments	Grain yield (ton/ha)	Grain yield (ton/ha)	Grain yield (ton/ha)	Grain yield (ton/ha)
Akaeze location				
PD	4.48	5.18	4.9	3.92
NPK	5.39	4.55	4.69	3.64
RHA	5.46	4.06	4.06	4.34
RH	4.62	4.62	4.55	4.13
CT	3.29	2.94	2.94	2.0
Mean	4.65	4.27	4.23	3.61
LSD (0.05)	0.52	0.52	0.52	0.52
LSD (0.05) Environments grain yield	0.4			
LSD (0.05) Environments x Amendments grain yield	NS			
Igweledoha location				
PD	7.52	4.9	5.11	4.55
NPK	6.28	4.9	4.69	4.62
RHA	6.65	4.9	4.48	4.06
RH	6.37	4.9	4.62	4.76
CT	3.08	2.8	3.01	2.14
Mean	5.98	4.48	4.38	4.03
LSD (0.05)	0.63	0.63	0.63	0.63
LSD (0.05) Environments grain yield	0.6			
LSD (0.05) Environments x Amendments grain yield	Ns			

PD = poultry dropping; NPK = Nitrogen:phosphorous:potassium; RHA = Rice husk ash; RH = Rice husk; CT = Control

Effect of *Sawah* Field Growing Environment and Soil Amendments on the Rice Grain Yield (ton/ha): Table 5 presents the effects of different sawah growing environments treated with different amendments on the rice grain yield. The result showed that rice grain yield was statistically increased by both sawah managed environments and the soil amendments, with complete sawah environment amended with poultry droppings giving the highest significant increase in the yield of 7.5 tons per hectare in Igweledoha location, while the highest statistical increase in grain yield was recorded at Akaeze from complete sawah environment treated with RHA. However, it was recorded here that the crop responded differently to the soil amendments and growing environments. Consequently, the underlying fact was that, in both locations, more grain yield was obtained in complete sawah growing environment. Ofori *et al.,* [29] and Nwite *et al.,* [21-22] reported that high grain yield responded to good water management conditions in sawah with optimum input level. Nwite *et al.,* [9] further shown that the good water management condition prevailing in the proper sawah growing environment might have contributed to the high grain yield response of rice to the investigated inputs.

CONCLUSION

The soils of the studied areas are low in pH and poor in plant nutrients. In spite of this, the sawah-managed system was able to improve the pH of the soil by raising the pH slightly in the two locations. Consequently, the sawah growing environments studied influenced the soil properties tested in various ways. Based on this, one can conclude that soil pH, OC, TN and other fertility index as well as CEC could be improved using complete sawah technology and soil amendments in inland valleys of Southeastern Nigeria. The study also indicated that the soil amendments used also improved the pH, TN, CEC and base saturation during the period in the two locations. Also rice grain yield was statistically increased by both sawah managed environments and the soil amendments.

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