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Effect of N fortified rice mill waste on soil chemical properties and yield of maize in Nigeria rainforest

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Organo-mineral nutrient sources are promising soil amendments for sustainable crop production in Nigeria. A field experiment was conducted at the Teaching and Research Farm of the Cross River University of Technology Obubra during the 2016 cropping season. The objective of the study was to evaluate the effects of nitrogen (N) and amended rice mill waste (RMW) on some soil chemical properties and yield of maize (*Zea mays* L.). The treatments consisted of 10 kg ha^{-1} RMW as control and 10 kg ha^{-1} of RMW amended with 10, 20, 30, 40 or 50 kg N ha^{-1}. The 6 treatments were replicated 3 times under RCBD with each experimental plot size measuring 4 × 3 m. All the treatments including control increased the chemical properties of the soil over the initial soil properties including total N, available P, SOM, pH and the exch. Cations; Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}. RMW + 40 kg N ha^{-1} and RMW 50 kg N ha^{-1} produced tallest plants, highest number of leaves per plant and largest leaf area of maize plants. RMW + 30 kg N ha-1, RMW + 40 kg N ha^{-1} and RMW + 50 kg N ha^{-1} produced the highest number of seeds per cob, highest plant dry matter and highest grain yield per unit area of 2.61 and 2.59 t ha^{-1} respectively in 2016 and 2.63 and 2.62 t ha^{-1} grain yield in 2017 while the least grain yield was obtained from the control (0.81 and 0.83 t ha^{-1} respectively for 2016 and 2017). Rice mill waste amended with 30 kg N ha^{-1} is therefore recommended for optimum economic yield of maize in Obubra Rainforest soil and the improvement of soil chemical properties for sustainability.

Key words: Fortified, rice mill waste, organo-mineral, N-fertilizer, maize, rainforest

INTRODUCTION

Recycling of agricultural waste is a great resource for sustainable crop yields in Nigeria. Soils in the humid tropics are poor in organic matter and available nutrients; hence their productivity and sustainability decline over time when subjected to continuous cultivation (Zingore et al., 2003).

The maintenance of soil organic matter is the basis of sustainable crop production in Nigeria and the tropics in general (Oladipo et al., 2005).

Organic based fertilizers have increased crop yield as well as soil quality (Babalola and Olowokere, 2005). Although organic manures are bulky and low in nutrient contents, Chiroma et al. (2006) noted that they are capable of valuable contribution to continuous demand of crop nutrients. They also contribute in conditioning the soil physically for improved crop environment such as structure of soil, reduced bulk density, increased porosity and water and nutrient retention. Rice mill waste (husk) abounds in rice growing and processing areas in bulk with low nitrogen contents which can be recycled for soil

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fertility improvement.

The fortification of this waste will enhance faster mineralization for nutrient release and other organic products of decomposition including humus for soil physical properties improvement. Moreover, maize is a staple crop that requires relatively high soil fertility with regards to N, P and K for sustainable yield.

MATERIALS AND METHODS

Location

The study was carried out at the ′Teaching and Research Farm of the Cross River University of Technology, Obubra Campus during the 2017 and 2018 cropping seasons on latitude 6° 06′ N and 8° 18′ E in the rainforest belt of Nigeria. Obubra is characterized by a mean annual rainfall density of 2250 - 2500 mm with an annual temperature range of 25 - 28°C.

Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) replicated 3 times. The treatments were six which consisted of: Control with no organic amendment, 10 t ha^{-1} rice mill waste sole, 10 t ha^{-1} rice mill waste + 1 t ha^{-1} poultry droppings, 10 t ha^{-1} rice mill waste + 2 t ha^{1} poultry droppings, 10 t ha^{-1} rice mill waste + 3 t ha^{-1} poultry droppings and 10 t ha^{-1} rice mill waste + 4 t ha^{-1} poultry droppings.

Experimental material and agronomic practices

The variety of maize used was OBA super 2. The rice mill wastes were obtained from the major rice mill, Ofodua in Obubra and the poultry droppings was obtained from the Department of Animal Science Farm, Cross River University of Technology, Obubra Campus. This was weighed according to the treatment level and nitrogen (N) fertilizer rates added to the wastes accordingly. These were incorporated on prepared seed bed and allowed for two weeks before sowing of the maize seeds. The source of the inorganic N was urea with 46% nitrogen.

Data collection

Soil sampling and processing

At the commencement of the experiment, composite soil samples were collected at random points within the experiment plots which were bulked using a soil auger at the 0 – 20 cm. The samples were air dried and sieved through a 2-mm mesh ready for laboratory analysis.

Plant sampling and analysis

A net plot of inner ridges for each treatment was used with five tagged plants for growth parameters. The grain yields for each net plot were extrapolated to yield in tonnes per hectare. Destructive sampling was used in each of the tagged plants in the net plot to determine plant dry matter and leaf nutrient contents.

Soil analysis

Routine analysis was conducted for the composite sample to determine the particle size distribution using the Bouyouchos hydrometer method as outlined by Udo et al. (2009). Soil pH was measured using a glass electrode pH meter and soil N by the macro Kjeldahl apparatus were applied as described by Udo et al. (2009).

Soil organic matter was analysed using the Walkley–Black wet Oxidation method as outlined by Page et al. (1982). The extract was titrated against ferrous sulphate. The organic carbon was estimated and it was further calculated that the percent organic matter in soil = % Org. C × 1.729.

Soil P was determined using the Bray 1 method as described by Page et al. (1982). Exchangeable cations and exchangeable acidity were extracted with KCl and passed through double titration as outlined by Udo et al. (2009).

Statistical analysis

Analysis of variance (ANOVA) for RCBD was performed on the maize plant height, number of leaves, leaf area, tissue N,P and K content and yield parameters using the computer software Genstat (Genstat, 2005). Fischers least significant difference (FLSD) was calculated at $P > 0.05$ to separate the means.

RESULTS AND DISCUSSION

Results of pre-treatment soil properties and rice waste are presented in Tables 1 and 2. The textural class of the soils is sandy loam with low organic matter content. The soils were also low in nitrogen, phosphorous, exchangeable cations and CEC.

The soils were moderately acidic in reaction. The N content of the rice mill waste was low (0.94% in 2016 and 0.95% in 2017) but with a concentration of calcium (Ca) of 2.21 cmol kg^{-1} and 2.19 cmol kg^{-1} respectively for 2016 and 2017 respectively.

The effects of amended rice mill waste on soil chemical properties are presented in Tables 3 and 4. The pH of the soils at the end of the experiment was raised from the pre–treatment 5.3 in 2016 and 5.46 in 2017 by all doses of the amended rice mill waste.

The pH was raised between 0.3 – 0.9 in 2016. This increase in pH followed the same trend in 2017. Soil organic matter (SOM) at the end of the experiment was increased by all the treatments above the initial levels of the experimental site for both 2016 and 2017 cropping seasons.

This increase (Table 3) was in the order of RMW + 10 kg N ha^{-1} = RMW + 0 kg N ha^{-1} = RMW + 20 kg N ha^{-1} > RMW + 30 kg N ha^{-1} > RMW + 40 kg N ha^{-1} = RMW + 50 kg N ha^{-1}.

Total N of the soils at the end of the experiment was increased by the fortified rice mill waste over the unfortified and the pre-treatment soil samples. Total N increased in the order of RMW + 50 kg N ha^{-1} = RMW + 40 kg N ha^{-1} >RMW+30 kg N ha^{-1} = RMW + 20 kg N ha^{-1} > RMW + 10 kg N ha^{-1} > RMW + 0 kg N ha^{-1} (Table 3).

Available P (Table 3) was increased by the amendment over the control and the initial soil. The application of N fortified rice mill waste increased available P by all rates

Table 1. Pre-cropping soil physical and chemical properties at the experimental site.

Parameter	2016	2017
Sand (g/kg)	853	797
Silt (g/kg)	79	106
Clay (g/kg)	68	98
Texture class	S/L	S/L
pH (water)	5.30	5.46
pH (KCl)	4.30	4.42
Organic matter (%)	1.26	1.34
Total nitrogen (g/kg)	0.8	0.9
Available P (mg/kg)	3.4	4.1
Exchangeable Ca (cmol kg^{-1})	2.60	2.52
Exchangeable K (cmol kg^{-1})	0.22	0.21
Exchangeable Mg (cmol kg^{-1})	1.01	1.20
Exchangeable Na (cmol kg^{-1})	0.17	0.18
Exchangeable acidity	2.75	2.73
CEC (cmol kg^{-1})	6.75	6.21

S/L = Sandy loam.

Table 2. Nutrients composition of the rice mill waste.

Property	Rice mill waste (RMW)	
	2016	2017
Total N (%)	0.94	0.95
Total P (mg/kg)	0.92	0.92
Total K (cmol/kg)	0.38	0.37
Ca (cmol/kg)	2.21	2.19
Mg (cmol/kg)	0.53	0.61
Na (cmol/kg)	0.21	0.22
Organic carbon (%)	38.1	38.41
C:N Ratio	40.53	40.43

Table 3. Soil pH, organic matter, N and available P at the end of cropping.

Treatment	pH	OM (%)	Total N (%)	Av. P (mg/kg)
RMW + 0 kg N ha^{-1}	6.2	1.62	0.08	21.2
RMW + 10 kg N ha^{-1}	6.1	1.84	0.10	23.1
RMW + 20 kg N ha^{-1}	6.2	1.79	0.09	24.3
RMW + 30 kg N ha_{-1}	6.3	1.86	0.11	23.1
RMW + 40 kg N ha^{-1}	6.3	1.85	0.11	22.1
RMW + 50 kg N ha^{-1}	6.4	1.83	0.13	21.4
		2017		
RMW + 0 kg N ha^{-1}	6.3	1.61	0.07	9.62
RMW + 10 kg N ha^{-1}	6.2	1.78	0.11	20.21
RMW + 20 kg N ha^{-1}	6.4	1.88	0.10	24.21
RMW + 30 kg N ha_{-1}	6.2	1.87	0.12	22.31
RMW + 40 kg N ha^{-1}	6.4	1.89	0.11	22.10
RMW + 50 kg N ha^{-1}	6.3	1.81	0.13	21.40

RMW =Rice mill waste.

Table 4. Exchangeable cations of the soil at the end of the cropping (cmol/kg).

Treatment	K	Ca	Mg	Na
RMW + 0 kg N ha^{-1}	0.51	3.34	2.01	0.12
RMW + 10 kg N ha^{-1}	0.41	3.29	2.12	0.08
RMW + 20 kg N ha^{-1}	0.38	3.58	1.88	0.10
RMW + 30 kg N ha^{-1}	0.37	3.61	1.89	0.11
RMW + 40 kg N ha^{-1}	0.41	3.55	1.85	0.08
RMW + 50 kg N ha^{-1}	0.43	3.62	1.79	0.09

applied over the control. The available P in the control plots was higher than the initial soil available P.

Results of exchangeable cations as presented in Table 4 show that the exchangeable cations Ca, K, Mg and Na at the end of the cropping did not differ among the treatments nor did they decrease compared with the initial soil exchangeable cations. Potassium and calcium however were increased above the initial soil level. RMW + 0 kg Nha^{-1} and RMW + 10 $kgNha^{-1}$ produced higher K and Ca values than the other amendments.

The pre-treatments low nutrients status and the moderately acidic reaction of these experimental sites is partly a characteristic feature of the rainforest soils due to high rainfall intensity and duration. This soil condition was reported by Chude (1998) and Harpstead (1973).

The increase in the pH of the post treatment and post-harvest soil reaction is an indication of the release of basic cations by these organic amendments to reduce activities of H^+ in soil.

This increase in soil pH due to application of organic amendments to soil has been reported by Olayinka et al. (1998), Natsher and Schwetnmann (1991), Ojeniyi et al. (1999) and Ano and Agwu (2005).

The observed increase in soil organic matter (SOM) by the application of rice mill waste amended with N in the study has been documented (Brady and Weil, 2002; Osundare, 2004; Akanbi and Ojeniyi, 2007). The lower SOM values in the higher inorganic N fortification amendments could be attributed to effect of inorganic nutrients that enhanced rapid mineralization of native SOM as earlier reported by Agboola (1990).

The higher total N content in the post-harvest soil was probably due to the enhanced mineralization of N, particularly the higher inorganic N amendments. The lower N values in unfortified rice mill waste treated soils could be the depletion of native N by microbes to initiate the degradation of the rice waste which had a high C/N ratio (Table 2).

This trend was reported by Eghball (2000), and Abdallahi and N'Dayeganiye (2000). The increase in available P that resulted from this soil amendment could be due to the increase in soil pH that can unlock fixed P in acidic soils. The use of organic manures and waste to raise soil pH and subsequent unlocking of P has been documented and all values were above the critical minimum level (Adeoye and Agloola, 1985).

The increase in the exchangeable Ca and K content in the post cropping soils and the non-decrease of Mg and Na compared with the pre-treatment soil values is an indication that the high Ca and K content of the rice mill waste released affected their concentration in the soils, and even with the crop uptake of the cations there was no depletion. This observed increase in the exchangeable cations from organic waste application individually or in combination with inorganic fertilizers has been documented (Olayinka, 1990; Odedina et al., 2007; Ayeni, 2010).

Growth, yield and yield components of maize

Result of growth, yield and yield components of maize as influenced by N fortified rice mill waste is presented in Tables 5 to 7.

The application of N amended rice mill wastes significantly ($P<0.05$) increased the growth, yield and yield components of maize (Tables 5 to 7). The amendments of rice mill waste (rice husk) with inorganic N fertilizer significantly increased the plant height, number of leaves and leaf nutrients content. RMW + 40 kg N ha^{-1} and RMW + 50 kg N ha^{-1} produced tallest plants (243.41 cm and 248.32 cm respectively in 2016 and 253.21 cm and 251.13 cm respectively in 2017 (Table 5). RMW + 40 kg N ha^{-1} and RMW + 50 kg N ha^{-1} produced largest leaf area of maize plants (810.42 cm^3 and 809.53 cm^3 respectively in 2016 and 788.41 cm^3 and 789.43 cm^3 respectively in 2017 (Table 5). The leaf N, P and K nutrients content was increased significantly by application of RMW + 40 kg N ha^{-1} and RMW + 50 kg N ha^{-1} above the other rates and the least nutrients concentration was in the control where rice mill waste was applied alone (Table 6). The application of the amended rice mill waste significantly increased number of seeds per cob, shoot dry matter and grain yield up to 30 kg N ha^{-1} and subsequently increasing these parameters marginally up to 50 kg N ha^{-1} (Table 7).

The increase in the yield and yield components of maize was in the order of 30 kg N ha^{-1} = 40 kg N ha^{-1} = 50 kg N ha^{-1} > 20 kg N ha^{-1} > 10 kg N ha^{-1} > 0 kg N ha^{-1} (Table 7).

Table 5. Mean plant height, number of leaves and leaf area of maize as affected by nitrogen fortified rice waste.

Treatment	Plant height (cm)	Number of leaves	Leaf Area (cm^3)
		2016	
RMW + 0 kg N ha^{-1}	168.02	11.32	632.10
RMW + 10 kg N ha^{-1}	201.21	12.21	739.61
RMW + 20 kg N ha^{-1}	211.24	11.80	746.34
RMW + 30 kg N ha^{-1}	225.31	12.40	760.21
RMW + 40 kg N ha^{-1}	243.41	13.53	810.42
RMW + 50 kg N ha^{-1}	248.32	13.42	809.53
FLSD (< 0.05)	18.42	0.86	16.11
		2017	
RMW + 0 kg N ha^{-1}	167.50	10.55	620.45
RMW + 10 kg N ha^{-1}	208.41	12.41	698.42
RMW + 20 kg N ha^{-1}	218.21	12.56	709.34
RMW + 30 kg N ha^{-1}	231.10	13.10	732.40
RMW + 40 kg N ha^{-1}	253.21	13.84	788.41
RMW + 50 kg N ha^{-1}	251.13	13.52	789.43
FLSD (< 0.05)	17.20	0.94	15.34

Table 6. Leaf nutrient concentration of maize as affected by application of amended rice waste.

Treatment	N	P	K
		2016	
RMW + 0 kg N ha^{-1}	2.24	0.42	0.74
RMW + 10 kg N ha^{-1}	2.65	0.48	0.79
RMW + 20 kg N ha^{-1}	2.78	0.52	0.85
RMW + 30 kg N ha^{-1}	3.21	0.58	0.84
RMW + 40 kg N ha^{-1}	3.80	0.62	0.91
RMW + 50 kg N ha^{-1}	4.42	0.66	0.94
FLSD (< 0.05)	0.19	0.08	0.06
		2017	
RMW + 0 kg N ha^{-1}	2.31	0.40	0.73
RMW + 10 kg N ha^{-1}	2.64	0.49	0.80
RMW + 20 kg N ha^{-1}	2.88	0.50	0.83
RMW + 30 kg N ha^{-1}	3.35	0.58	0.85
RMW + 40 kg N ha^{-1}	3.72	0.65	0.91
RMW + 50 kg N ha^{-1}	4.64	0.66	0.92
FLSD (< 0.05)	0.78	0.11	0.08

The increase in pH, SOM, total N, available P and exchangeable cations due to the application of the amended rice mill waste was manifested in the crop performance. This growth and yield results of this experiment agrees with the assertion of Ojeniyi et al. (1999) where they observed highest maize yield from organomineral fertilizer. A combination of organic and inorganic fertilizers resulted in increased growth and yield of maize (Ayoola and Makinde, 2007; Dania et al., 2012). The high concentration of N, P and K in the leaf of maize in this study due to the amendment of rice mill waste agrees with the findings of Lawal et al. (2010) who reported higher uptake of NPK from organo-mineral fertilizer by yam. The low yield of maize in the control (RMW + 0 kg N $ha^{-1)}$ was probably due to the carbonaceous rice husk that slowed down the rate of

Table 7. Yield and yield components of maize as influenced by N amended rice mill waste.

Treatment	No. of seeds per cob	Dry matter (g/plant)	Grain yield (t/ha)
2016			
RMW + 0 kg N ha^{-1}	308	6.42	0.81
RMW + 10 kg N ha^{-1}	319	7.21	1.18
RMW + 20 kg N ha^{-1}	382	7.42	2.42
RMW + 30 kg N ha^{-1}	400	8.22	2.54
RMW + 40 kg N ha^{-1}	398	8.26	2.61
RMW + 50 kg N ha^{-1}	401	8.26	2.59
FLSD (< 0.05)	9.41	0.61	0.08
2017			
RMW + 0 kg N ha^{-1}	305	6.51	0.79
RMW + 10 kg N ha^{-1}	324	7.40	1.20
RMW + 20 kg N ha^{-1}	389	7.48	2.30
RMW + 30 kg N ha^{-1}	403	8.21	2.58
RMW + 40 kg N ha^{-1}	402	8.26	2.63
RMW + 50 kg N ha^{-1}	403	8.30	2.62
FLSD (< 0.05)	9.62	0.10	0.09

RMW – Rice mill waste.

mineralization of that amendment as earlier stated by Rajcan and Tollenaar (1999).

Conclusion

The amendment of rice mill waste with inorganic nitrogen fertilizer was efficient in increasing soil nutrients status of total N, available P, organic matter and Ca as well as exchangeable cations of K, Mg, Ca and Na and ultimately increased yield and yield components of maize. The fertilization of this rice waste with 30 kg N ha^{-1} is economical for the optimum yield of maize and improvement of soil chemical properties in this agro ecology.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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