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Influence of Human Urine on Rice Grain Yield (*Orzya sativa L.*) and Selected Soil Properties in Abakaliki Southeastern Nigeria

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***Abstract*— *An experiment was carried out at Abakaliki Southeastern Nigeria to study the influence of human urine on rice grain yield, selected soil physical and chemical properties in Abakaliki southeastern Nigeria in 2014 and 2015. The experiment was arranged in randomized complete block designed (RCBD) with human urine applied in the following rates: A = Control (no application of treatment); B = 2 kilolitres/ha; C = 4 kilolitres/ha and D = 6 kilolitres/ha. Treatments were not applied in 2015 to test the residual effect. In general, human urine improved rice grain yield, bulk density, total porosity, hydraulic conductivity, moisture content, organic carbon, total nitrogen, C/N ratio, pH, available phosphorus and exchangeable bases in 2014 it was applied and the following year as residual effect. An increase in the rate of urine application also resulted to an increase in rice grain yield and higher improvement in soil properties studied.*

Keywords* — *Effects, faeces, sewage, rice grain, urine

I. INTRODUCTION

Use of human urine as alternative to synthetic fertilizer has not been put into usage at Abakaliki, the study area. The reason is that the method of collection is very difficult as most human beings urinate on land directly or discharge mixture of urine and faeces to tanks and pit latrine resulting to sewage thereby making collection of pure urine difficult. According to [1], more than 95% of sewage in developing countries do not undergo any form of treatment as to use them as alternative to synthetic fertilizer without adverse effect. Also, the use of synthetic fertilizer as amendments in most developing countries for crop productions can no longer be relied upon since it is too costly, unavailable when needed by farmers [2] and leads to soil degradation on continuous usage. Thus, there is a need to consider alternative sources of synthetic fertilizer such as human urine due to the fact that it could be readily available and cheap.

Unlike faeces, human urine from a healthy person is generally sterile and can be used as a fertilizer without recourse to any further purification [3]. However, even sterile human urine can get contaminated from faeces during collection due to dysfunctional collection systems or improper use of urine diversion toilets. It is therefore recommended to sanitize human urine before applying it to crops [4]. According to [5] storage periods up to 6 and 3 months at about 4 °C and above 20 °C, respectively are necessary for a safe handling of human urine. Human urine contains most of the nutrients of human excreta, and it can yield considerable amounts of N, P, K, S, Ca, and Mg [6].

The objective of the study was to determine the influence of human urine on rice grain yield, selected soil physical and chemical properties in Abakaliki southeastern Nigeria.

II. MATERIALS AND METHODS

2.1 Experimental site

The study was conducted at Abakaliki Southeastern Nigeria in 2014 and 2015 cropping seasons. Abakaliki coordinates at latitude 06°2'N and longitude 08°05'E at an altitude of 447.2 m above mean sea level in the derived savannah of the southeast agro-ecological zone of Nigeria. The mean annual minimum rainfall is 1800 mm while the mean annual maximum rainfall is 2000 mm distributed between April and early November. There is short spell in August referred to as "August break". At onset of rainfall, it is violet and often torrential lasting for 1 – 2 hours. The minimum temperature is 27°C while maximum is 31°C. The relative humidity is highest during rainy season (80%) and declines to 60% in dry season especially at harmattan period. The bedrock geology is shale residuum due to successive marine deposit. The soils belong to the order Ultisol classified as Typic Haplustult [7].

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2.2 Sources of materials, land preparation and experimental design

Three containers were provided for the urine collection at one of the Primary Schools in Abakaliki, Ebonyi State, Nigeria. Teachers and pupils in the school were advised to urinate into any of the three containers for 2 weeks. At the end of each day, urine in the three containers were collected, mixed together and stored in air-tight plastic container at the temperature of 25ºC. At the expiration of the 2 weeks of collection, the urine was allowed for 6 months before application in the field. Faro 52 (the test crop) was bought from Ebonyi State Agricultural Development Programme.

The experiment was laid out in Randomized Complete Block Design (RCBD) while the 20 plots, each 3 X 4 m were used. Each plot and block was separated by 0.5 and 1.0 m, respectively. Four treatments replicated five times were used for the study. Treatment details are – A = Control (no application of amendment); B = 2.4 litres/plot equivalent to 2 kilolitres/ha; C = 4.8 litres/plot equivalent to 4 kilolitres/ha and D = 7.2 litres/plot equivalent to 6 kilolitres/ha.

Treatments were applied three weeks after planting of rice seeds.

Four rice seeds were planted per hill three weeks before treatment application at the inter and intra row spacing of 25 cm and 20 cm, respectively whereas the planting depth was 1.5 cm. Hand weeding was used to control weeds throughout the period of the experiment. The experiment was rain fed and neither pesticides nor synthetic fertilizers were applied. The same procedure was repeated in the second year of the experiment but without the application of treatment to test the residual effect.

2.3 Sampling and laboratory analysis

Undisturbed core soil samples of 157 cm^3 and auger soil samples were collected from all the plots at 90 days after planting (DAP) from four observational points each cropping season and used for the determination of the physical and chemical properties of the soil in the laboratory. Auger soil samples were collected at 0 – 20 cm soil depth. Proximate analysis of urine and initial soil analysis were also carried out and the results are as presented on Table 1. Bulk density (Bd) was determined using the method described by [8]. Total porosity (Tp) was determined using the formular –

Tp = 100(1 – Bd/Pd) where Pd = particle density assumed to be 2.65 gcm^{-3}. Hydraulic conductivity (Hc) was determined as described by [9]. Moisture content (Mc) was determined by calculation as outlined by Obi [10]. Particle size distribution was determined using Bouyoucous hydrometer method as described by [11]. Soil pH was determined using a suspension of soil and distilled water in the ratio of 2:5 – soil: water [12].

Table.1: Proximate analysis of urine and initial soil properties

Test parameter	Urine	Soil
Sand	-	680 gkg^{-1}
Silt	-	210 gkg^{-1}
Clay	-	110 gkg^{-1}
Bulk density	-	1.66 gcm^{-3}
Texture	-	Sandy loam
Total porosity	-	37.36%
Hydraulic conductivity	-	19.58cmhr^{-1}
Moisture content	-	26.16%
pH	9.3	6.15
Total N	8.6 gL^{-1}	0.08%
Total Carbon	8.4 gL^{-1}	0.85%
C/N ratio	0.98	10.63
Available P	0.09 gL^{-1}	18.23 mgkg^{-1}
Ca	0.4 gL^{-1}	2.1 Cmol(+)kg^{-1}
Mg	0.13 gL^{-1}	0.8 Cmol(+)kg^{-1}
K	1.3 gL^{-1}	0.2 Cmol(+)kg^{-1}
Na	1.8 gL^{-1}	0.02 Cmol(+)kg^{-1}

Total nitrogen was determined using modified kjeldahl digestion procedure [13]. Available phosphorus was determined by Bray 11 method [14]. Organic carbon was determined by the method of [15]. Exchangeable bases were determined using [16] method. At maturity, 10 rice plants per plot were selected and tagged [17]. The grain yields from the tagged plants were harvested, dried to 11 % moisture content. Grains/plot was weighed and then converted to its hectare equivalent. Statistical analysis of the data was carried out using the General Linear Model of SAS software for Randomized Complete Block Design [18] while treatment means were separated using the Duncan's Multiple Range Test (DMRT).

III. RESULTS

3.1 Soil physical properties

The influence of urine on soil bulk density and total porosity is as presented on Table 2. The application of urine in 2014 at B, C and D significantly decreased bulk density and increased total porosity in 2014 and 2015 when compared to control. The higher the increase the lower the decreased in bulk density and higher the increased in total porosity. Each treatment recorded higher bulk density and lower total porosity in 2015 than 2014.

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Table.2: Influence of urine on soil bulk density and total porosity

Treatment	Bulk density (gcm^{-3})		Total porosity (%)	
	2014	2015	2014	2015
A	1.67^{a}	1.69^{a}	36.98^{d}	36.23^{d}
B	1.62^{a}	1.63^{b}	38.87^{c}	38.49^{c}
C	1.58^{bc}	1.60^{c}	40.38^{b}	39.62^{b}
D	1.54^{c}	1.56^{d}	41.89^{a}	41.13^{a}

Note: Means in the same column with the same letter do not differ significantly at $P < 0.05$.
A = Control (no application of amendment); B = 2 kilolitres/ha; C = 4 kilolitres/ha and D = 6 kilolitres/ha

Table 3 shows the influence of urine application on soil hydraulic conductivity and moisture content. Hydraulic conductivity was significantly increased with an increase in the application of urine in 2014 cropping season. Similarly, the residual effect in hydraulic conductivity was significantly higher with those plots treated with higher rates of urine. Also, all the urine treated plots had higher hydraulic conductivity in 2014 than the residual year. Lowest moisture content of 25.45 % was observed in control while moisture content in urine treated plots ranged between 27.08 – 28.46 %. The order of increase in moisture content in residual year was D > C > B > A.

Table.3: Influence of urine on soil hydraulic conductivity and moisture content

Treatment	Hydraulic conductivity ($cmhr^{-3}$)		Moisture content (%)	
	2014	2015	2014	2015
A	17.32^{d}	19.23^{c}	25.45^{d}	24.86^{cd}
B	20.68^{c}	19.98^{c}	27.08^{c}	26.08^{bcd}
C	23.56^{b}	22.36^{b}	28.13^{ab}	27.34^{abc}
D	31.21^{a}	24.01^{a}	28.46^{a}	27.98^{ab}

Note: Means in the same column with the same letter do not differ significantly at $P < 0.05$.
A = Control (no application of amendment); B = 2 kilolitres/ha; C = 4 kilolitres/ha and D = 6 kilolitres/ha

3.2 Soil chemical properties

The influence of urine on pH and available P is as shown on Table 4. The Table also, show significant ($p < 0.05$) changes in pH and available P among the treatments studied. Soil pH and available P increased with an increase in urine applied. Also, urine recorded lower effect on residual year than the year in which urine was applied.

Table.4: Influence of urine on pH and available phosphorus

Treatment	pH		Available phosphorus ($mgkg^{-1}$)	
	2014	2015	2014	2015
A	6.01^{bc}	5.98^{ab}	15.23^{d}	13.23^{d}
B	6.23^{abc}	6.18^{a}	22.36^{c}	15.96^{c}
C	6.25^{a}	6.21^{a}	25.01^{b}	17.28^{b}
D	6.25^{a}	6.23^{a}	27.36^{a}	21.23^{a}

Note: Means in the same column with the same letter do not differ significantly at $P < 0.05$.
A = Control (no application of amendment); B = 2 kilolitres/ha; C = 4 kilolitres/ha and D = 6 kilolitres/ha

Table 5 shows influence of urine on organic carbon, total nitrogen and C/N ratio. There was non-significant ($p < 0.05$) changes among the treatment with regard to organic carbon in both 2014 and 2015 with the values of organic carbon observed residual year lower than the organic carbon observed in the year of treatment application.
Urine application significantly increased the total N in both the two years of the study. Also, the increase in the urine application resulted to an increase in total N in both 2014 and 2015 with higher total N in all the treatments in 2014. The order of increase in C/N ratio in both year of treatment application and residual year was D > C > B > A. Unlike other parameters in this study, C/N ratios were higher in the residual year than the year of treatment application.

Table.5: Influence of urine on organic C (%), total N (%) and C/N ratio

Treatment	Organic C		Total N		C/N ratio	
	2014	2015	2014	2015	2014	2015
A	0.79^{a}	0.75^{a}	0.06^{c}	0.04^{d}	13.17^{a}	18.75^{a}
B	0.80^{a}	0.77^{a}	0.12^{b}	0.10^{c}	6.67^{b}	7.70^{b}
C	0.79^{a}	0.76^{a}	0.14^{a}	0.12^{abc}	5.64^{c}	6.33^{c}
D	0.79^{a}	0.78^{a}	0.15^{a}	0.14^{a}	5.27^{cd}	5.57^{d}

Note: Means in the same column with the same letter do not differ significantly at $P < 0.05$.

A = Control (no application of amendment); B = 2 kilolitres/ha; C = 4 kilolitres/ha and D = 6 kilolitres/ha

The influence of urine on exchangeable bases is presented on Table 6. There was a significant increase in Ca with an increase in urine application in the two years of the experiment with 2015 recording the lower values of Ca when compared to 2014. Increase in urine application resulted to significant increase in Mg in both years of the experiment with lower values observed in the residual experiment. The order of K increase in both 2014 and 2015 was D > C > B > A while values were higher in 2014 than 2015. Control had the lowest Na value of 0.02 and 0.01 $Cmol(+)kg^{-1}$ in 2014 and 2015, respectively while Na in plots treated with urine ranged between 0.03 – 0.04 $Cmol(+)kg^{-1}$ in 2014 and 0.02 $Cmol(+)kg^{-1}$ in 2015.

Table.6: Influence of urine on exchangeable bases (Cmol(+)kg^{-1})

Treatment	Ca		Mg		K		Na	
	2014	2015	2014	2015	2014	2015	2014	2015
A	1.8^{d}	1.2^{d}	0.6^{c}	0.4^{c}	0.16^{c}	0.12^{d}	0.02^{b}	0.01^{ab}
B	2.2^{c}	2.0^{c}	0.9^{b}	0.7^{b}	0.22^{b}	0.18^{b}	0.03^{ab}	0.02^{a}
C	2.6^{b}	2.4^{b}	1.0^{ab}	0.9^{a}	0.22^{b}	0.16^{c}	0.03^{ab}	0.02^{a}
D	3.1^{a}	2.8^{a}	1.1^{a}	0.9^{a}	0.26^{a}	0.20^{a}	0.04^{a}	0.02^{a}

Note: Means in the same column with the same letter do not differ significantly at $P < 0.05$.
A = Control (no application of amendment); B = 2 kilolitres/ha; C = 4 kilolitres/ha and D = 6 kilolitres/ha

3.3 Rice grain yield
Table 7 shows the influence of urine on rice grain yield. Increase in the application of urine resulted to a significant increase in rice grain yield harvested in the year of treatment application and the residual year. In the year of treatment application, control plot recorded rice grain yield of 2.56 t ha^{-1} while rice grain yield observed in urine treated plots ranged between 4.78 – 6.08 t ha $^{-1}$. Whereas in the residual year, control had rice grain yield of 2.32 t ha^{-1} and rice grain yield in urine treated plots ranged between 3.43 – 4.24 t ha^{-1}.

Table.7: Influence of urine on rice grain yield (t ha^{-1})

Treatment	2014	2015
A	2.56^{d}	2.32^{c}
B	4.78^{c}	3.43^{b}
C	5.18^{b}	4.12^{a}
D	6.08^{a}	4.24^{a}

Note: Means in the same column with the same letter do not differ significantly at $P < 0.05$.
A = Control (no application of amendment); B = 2 kilolitres/ha; C = 4 kilolitres/ha and
D = 6 kilolitres/ha

IV. DISCUSSION

Results of initial soil properties (Table 1) showed that the soil studied was a sandy loam. Sandy loam is highly permeable and allows large quantities of nutrients to pass through it [19]. As a result of this high permeability, soil of this texture contains poor plant nutrients and, hence, inorganic or organic amendment is necessary for good crop production. Initial soil pH was slightly acidic with a pH of 6.15. This slightly acidic nature could be attributed to low rainfall and high cropping intensity [20]. According to [21] organic carbon was low (0.85 %). This might be attributed to low natural organic matter returns and other human factors such as bush burning and crop removal. The total nitrogen was very low with the value of 0.08 %. This very low nitrogen content was a reflection of the organic carbon content in the soils [22]. Similarly, according to [21] exchangeable Mg and Ca were moderate with the values of 0.8 and 2.1 Cmol(+)kg^{-1}, respectively. The exchangeable K was very low with value of 0.2 Cmol(+)kg^{-1} which was equal to 0.20 Cmol(+)kg^{-1} regarded as the critical limit of exchangeable K in the soils [23]. The exchangeable Na was also low with the value of 0.02 Cmol(+)kg^{-1}.
Similarly, Table 1 showed that the various nutrients contained in urine were of higher concentration than that of soil, hence the need to use urine as soil treatment. [6] showed that human urine contained considerable amounts of primary crop nutrients such as N, P and K; and secondary nutrients such as S, Ca and Mg; and that urine application as an organic fertilizer in small-scale agricultural plots have shown the potential to match the crop yield quantity and quality commonly achieved with mineral fertilizers. [24] in his study of effect of different urine sources on soil chemical properties and maize yield in Abakaliki, Southeastern Nigeria observed significant higher effect of different sources of urine on to N, available P, exchangeable Ca and Mg when compared to the control. According to [25] human excreta improves maize crop production and water productivity in rain-fed agriculture. [24] also obtained significantly higher maize grain yield in plots treated with urine sources than the control. Also, [26] and Njoku and [17] showed that organic amendments improve soil physical properties such as bulk density, hydraulic conductivity, total porosity and moisture content which results to better crop yield. [27] on their study of effects of animal faeces and their extracts on maize yield in an Ultisol of eastern Nigeria showed that animal faeces and their extracts significantly increased the soil organic matter, exchangeable bases, cation exchange capacity and the available phosphorus and with the increase of soil nutrients following the application of the organic wastes, all amendments increased maize performance over the control.

V. CONCLUSION

The study showed that nutrients content of the urine have higher magnitude than the nutrients in the soils hence, the need to use urine as soil amendment. The application of urine in different rates improved rice grain yield and soil properties in this study. Unlike faeces, urine from a healthy person is generally sterile and can be used as a fertilizer without recourse to any further purification. However, urine can get contaminated from faeces during

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collection due to failure of the collection systems or improper use of urine diversion toilets. It is therefore recommended to sanitize urine before applying to crops.

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