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The use of human urine as an organic fertilizer in the production of okra (*Abelmoschus esculentus*) in South Eastern Nigeria

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ABSTRACT

Greenhouse and field experiments were conducted to evaluate the response of okra to different levels of human urine (0, 10,000, 15,000 and 20,000 L/ha) and 400 kg/ha NPK 15:15:15 inorganic fertilizer in five riverine communities of Cross River State, Nigeria. The soils of the communities are generally acid with low organic matter, total nitrogen, exchangeable cations, but were rated medium in available P. The pH of the urine was alkaline with moderate amount of nutrients. There was a significant ($P < 0.05$) increase in nutrient uptake with application of either urine or inorganic fertilizer compared with the control. Application level of 20,000 L urine/ha significantly increased the growth and yield attributes of okra plants relative to NPK fertilizer, while 15,000 L urine/ha had a similar effect on okra plant as the inorganic fertilizer. The inert potentials of human urine as a good source of organic fertilizer are discussed.

1. Introduction

The common okra (*Abelmoschus esculentus*) is an important vegetable crop highly cherished for its succulent leaves and fresh pods in Nigeria and other parts of the world. World production of okra as fruit–vegetable is estimated at 6 million tonnes/year (Siemonsma and Kouame, 2004). West and Central Africa account for about 10% world production. The fruits are exported by some countries of Asia, the Caribbeans and Africa to Europe and America. Kenya is a dominant supplier to the United Kingdom and other European countries. Other important exporting countries are Brazil, Cyprus, Mali, Senegal and Surinam (Joy, 1987). Young immature okra fruits are consumed cooked or fried. In West Africa, they are usually boiled in water to make slimy soups and sauces (Burkhill, 1997). Young leaves are commonly used as spinach. Okra mucilage is suitable for medical and industrial applications (Burkhill, 1997). Roasted okra seeds are used in some areas as a substitute for coffee. The seeds contain about 20% protein (similar in amino acid composition to soyabean) and 20% oil (similar in fatty acid composition to cotton-seed oil) (Siemonsma and Kouame, 2004).

The common okra tolerates different soil types but performs well in a well-drained sandy loam with pH 6–7, and a high content of organic matter. The uptake of minerals by okra is reportedly high. Estimate suggests total nutrient uptake per ha of about 100 kg N, 10 kg P, 60 kg K, 80 kg Ca and 49 kg Mg for a fruit yield of 10 t/ha (Siemonsma and Kouame, 2004). With such heavy nutrient demand, marginal soils must be amended with fertilizer for optimum yield. Many researchers have evaluated the response of the common okra to both organic and inorganic fertilizer treatments (Akanbi et al., 2004; Asiegbu, 1987; Awodun and Olafusi, 2007; Olomilua et al., 2007; Uko et al., 2009). In all these trials, the authors observed a positive response by okra plant to fertilizer application with respect to growth and yield attributes. In Nigeria, mineral fertilizers are expensive and not accessible to farmers when needed (FFTC, 1997). Moreso, the attendant hazards to soil and crop injuries associated with the application of inorganic fertilizers presents organic manure as a good substitute (Stope et al., 1984).

In Nigeria, many trials on organic manure had utilized livestock/avian droppings, farm yard manure, compost, etc. Little work has been done on the potentials of human waste in crop production (Sridhar et al., 2005). According to Verchuur (1993), organic farming is gaining wide acceptance in the country with tremendous speed. The use of human urine and faeces for crop production has been widely practiced in many parts of the world. The introduction of ecological sanitation (Ecosan) toilets in some African countries has awaken interest in the use of urine in crop production in this part of the world. Ecosan toilets guarantees source-separation of urine from faeces. Urine has been reported as a high quality, low-cost alternative to chemical fertilizer (Kirchmann and Pettersson, 1995). In Mexico, Guadarrama et al. (2001) evaluated

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the efficiency of human urine as a fertilizer against compost and no fertilizer treatments on greenhouse-grown lettuce. Application rate of 150 kg N/ha urine equivalent gave significantly the highest yield. A comparison among human urine, dried chicken manure and meat + bone meal at three N fertilization rates was made on field trials with winter wheat (LundstrÖm and Lindén, 2001). Increase in yield was 18 kg, 14 kg and 10 kg grain/kg N for human urine, dried chicken manure and meat + bone meal, respectively based on the average of the three N-rates. In Germany, Simons and Clemens (2004) observed that the fertilizing effect of urine was higher than that of mineral fertilizer in the production of barely. In Ethiopia, Sundin (1999) reported that the yields of Swiss chard fertilized with urine were four times those unfertilised. Bath (2003) observed that the N-efficiency of urine was high (47–66%) and compared well with mineral fertilizers. Morgan (2003) also reported higher yields of vegetables treated with urine than unfertilised plots in Zimbabwe. The establishment of Ecosan toilets in riverine areas of Odukpani Local Government Area of Cross River State, Nigeria by UNICEF is a welcomed development health-wise. However, the utilization of the by-products of the toilets (faeces and urine) in crop production calls for scientific investigation. Thus, this research was initiated with the objective of evaluating the response of okra to different levels of human urine compared with an inorganic fertilizer.

2. Materials and methods

2.1. Study area

The study area lies between latitudes 5°00′ and 5°30′N as well as longitudes 7°32′ and 08°24′ east of the Greenwich Meridian (Fig. 1). Eniong Creek basin is drained by Eniong Creek and is dotted with island villages, namely Okpo, Obio Usiere, Ntan Obu, Atan Onoyom and Isong Inyang. The study area include Mbiabo Edere at the east bank of the Cross river, Okpo, Obio Usiere, Ntan Obu and Atan Onoyom all in Odukpani Local Government Area of Cross River State, Nigeria. The topography is nearly flat and the soil parent materials consist of alluvial deposits and Eze-Aku shale formation. The area is characterized by annual rainfall of 2250–2500 mm, annual temperature range of 26–28 °C, relative humidity of 70–80% and is located at elevation of about 5–25 m above the mean sea level. The area is flooded during the rainy season and the flood readily recedes in the month of November leaving extensive floodplains for the cultivation of different crops.

2.2. Soil sampling and analytical procedure

Composite soil samples were taken at a depth of 0–15 cm and 15–30 cm from five different communities, namely Mbiabo Edere,

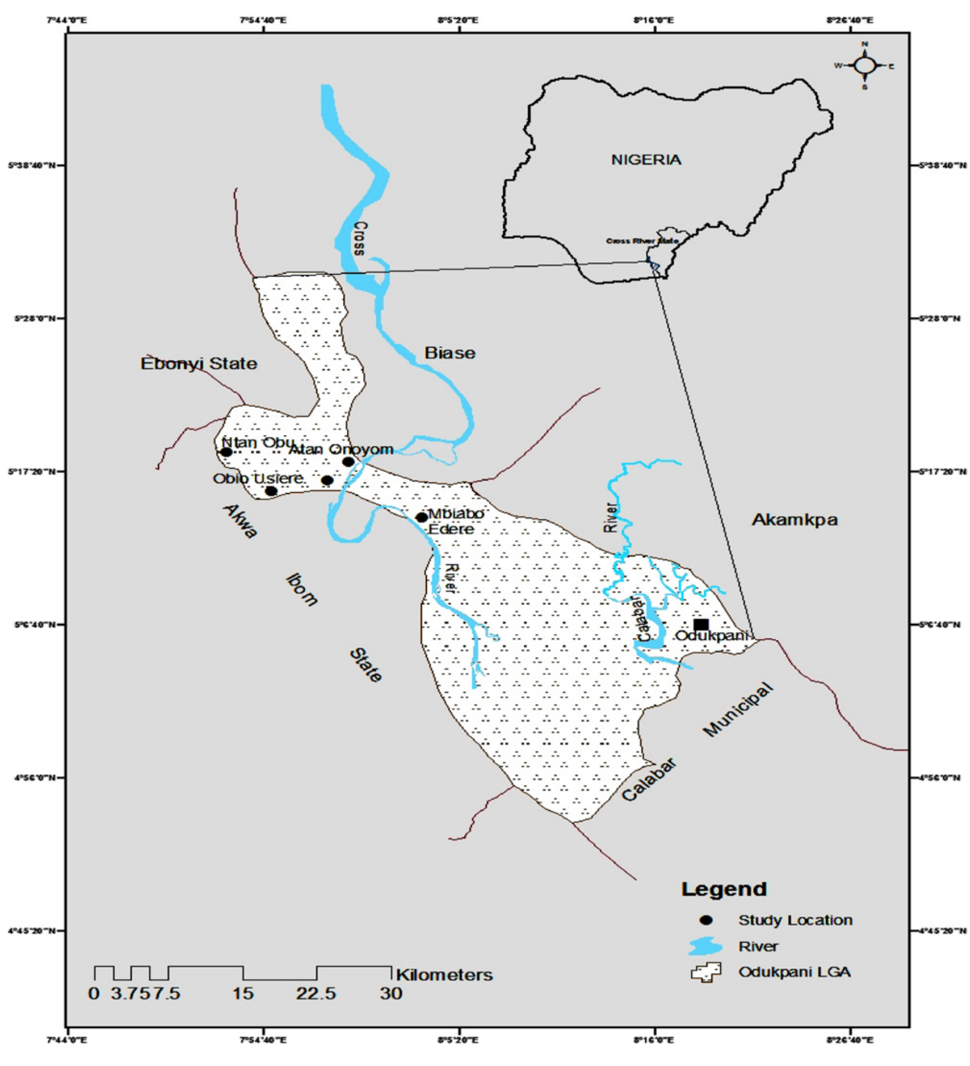

Fig. 1. Odukpani local government area showing study locations.

Table 1
Physico-chemical characteristics of soils collected from ecological sanitation programme areas in odukpani local government area, Cross River State.

Physico-chemical properties	Location										Surface mean	Subsurface mean
	Mbiabo Ediere		Obio Usiere		Atan Onoyom		Okpo		Ntan Obu			
	Depth 0–15	Depth 15–30	Depth 0–15	Depth 15–30	Depth 0–15	Depth 15–30	Depth 0–15	Depth 15–30	Depth 0–15	Depth 15–30		
Particle size (%)												
Sand	81.3	83.3	80.3	72.3	80.3	81.3	66.3	66.3	80.3	81.3	77.7	76.9
Silt	14.7	10.7	15.7	13.7	4.7	3.7	14.7	12.7	4.7	3.7	10.9	8.9
Clay	4.0	6.0	4.0	14.0	15.0	15.0	19.0	21.0	15.0	15.0	11.4	14.11
Texture	ls	ls	ls	sl	ls	ls	sl	sl	ls	ls	–	–
pH	6.0	6.2	6.4	6.1	5.1	5.1	6.2	6.6	5.5	5.4	5.8	5.9
Org. C (%)	0.92	0.48	1.16	0.54	0.46	0.24	1.18	0.99	0.92	0.40	0.93	0.53
Total N (%)	0.08	0.04	0.09	0.04	0.04	0.02	0.10	0.08	0.07	0.03	0.08	0.04
C:N ratio	12.0	12.0	13.0	14.0	12.0	11.0	12.0	12.0	13.0	13.0	12.0	13.0
Avail. P ($mg\,kg^{-1}$)	28.0	44.0	6.0	4.0	12.0	1.20	16.0	15.0	9.0	5.0	14.0	16.0
Exch. bases ($cmol\,kg^{-1}$)												
Ca	5.60	4.20	4.00	3.20	0.80	1.20	1.00	11.20	2.80	2.80	4.84	4.52
Mg	0.60	0.40	0.80	0.40	0.60	0.60	5.20	3.40	0.60	1.20	1.56	1.20
K	0.11	0.10	0.10	0.09	0.07	0.08	0.15	0.14	0.08	0.09	0.10	0.10
Na	0.08	0.07	0.08	0.07	0.05	0.06	0.11	0.12	0.07	0.06	0.08	0.08
EA ($cmol\,kg^{-1}$)	1.00	1.32	0.76	0.84	2.36	2.44	0.56	0.20	2.12	2.04	1.36	1.37
ECEC ($cmol\,kg^{-1}$)	7.39	6.09	5.74	4.60	3.88	4.38	17.02	15.06	5.67	6.19	7.94	7.26
BS (%)	86.00	78.00	87.00	82.00	39.00	44.00	96.00	98.00	63.00	67.00	74.00	74.00

Ntan Obu, Obio Usiere, Okpo and Atan Onoyom. Also, for the greenhouse experiments, surface soils (0–15 cm) were collected from the same communities. The samples were taken to the laboratory and air dried, ground and sift through 2 mm mesh sieve.

Soil pH was determined in 1:2 soil/water ratio. Particle size analysis was carried out by Bouyoucos (1951) hydrometer method. The method of Walkley and Black as outlined by Juo (1979) was used in the determination of organic carbon. Available phosphorus was determined by Bray and Kurtz (1945) No. 1 method. Exchangeable acidity was extracted with 1NKCl solution and the acidity in the extract measured by titration with 0.05 N NaOH. Exchangeable bases were extracted with neutral 1 N NH_4OAC; pH 7.0; the potassium and sodium in the extract were determined by flame photometry while calcium and magnesium were determined by Versenate EDTA titration (Jackson, 1962).

Total nitrogen was determined by the micro-kjeldahl digestion method (Jackson, 1962). Urine samples stored for two months in sealed jerry cans were collected from the respective communities were analyzed for chemical properties using appropriate methods.

2.3. Greenhouse trial

For the greenhouse trial, perforated plastic pots were filled with 3 kg of the surface soil from each community. Four seeds of okra cultivar "LD88-1" obtained from National Horticultural Research Institute (NIHORT), Ibadan, Oyo State, Nigeria were planted per pot. Two weeks after emergence, they were thinned to one per pot. Urine collected from ECOSAN toilets from the respective communities were applied at the rate of 10,000, 15,000 and 20,000 L/ha, equivalent to 15 ml, 22.5 ml and 30 ml/pot; respectively at two weeks after planting. Plants that received no urine treatment served as control. An inorganic fertilizer NPK:15:15:15 was applied at the rate of 400 kg/ha, equivalent to 0.60 g/pot. There were three replicates in each five treatments laid out in a completely randomized design (CRD). Plants were watered daily and grown to full maturity. Data were collected on plant height, number of leaves, shoot dry weight/plant, number of pods and fresh weight of pod per plant at harvest. Pods were harvested on a 4-day interval and the total yield obtained through the summation of such yields. For shoot dry weight, after final harvest, the whole plant was uprooted and the shoot system cut off from the root system and oven-dried in an envelop in a hot air oven at 70 °C to constant weight.

2.4. Field trial

Field experiments were done in two communities (Mbiabo Edere and Obio Usiere). In each community, a plot of land with dimensions 20 m × 20 m was demarcated into four blocks after clearing the vegetation. Each block was divided into five plots each measuring 3 m × 2 m and plots were separated from each other with a gap of 1 m. The plots were tilled manually with a shovel and three seeds of okra CV. "LD88-1" were planted at a spacing of 40 cm between rows and 30 cm within a row and later thinned to one per stand giving a population of 50 plants/plot (83,333 plants/ha). Urine was applied two weeks after transplanting at the rate of 120 ml, 180 ml and 240 ml per okra stand equivalent to 10,000, 15,000 and 20,000 L/ha. Plots with no urine applied served as the control. The NPK 15:15:15 fertilizer was applied at the rate of 400 kg/ha (4.9 g/stand) through ring method. Plants were watered thrice weekly. The five treatments were laid out in a randomized complete block design (RCBD) and replicated four times. The plots were manually weeded twice, three weeks after planting and seven weeks after planting. At the beginning of flowering, leaf samples were collected and their dry matter was determined after heating at 105 °C for 24 h and the ash content obtained by heating at 500 °C for 4 h. Extraction and nutrient determinations were done

Table 2
Chemical composition of human urine from four communities in Odukpani Local Government Area, Cross River State, Nigeria.

Parameters	Samples				Mean
	1	2	3	4	
pH	8.90000	9.00000	9.20000	9.00000	9.00000
Total organic carbon (g/L)	5.62000	5.18000	5.97000	5.45000	5.56000
Total nitrogen (g/L)	4.97000	4.42000	4.65000	4.28000	4.58000
Total phosphorus (g/L)	0.27000	0.25000	0.24000	0.28000	0.26000
Potassium (g/L)	0.85000	0.94000	0.76000	0.92000	0.87000
Calcium (g/L)	0.01800	0.01600	0.01700	0.01625	0.01681
Magnesium (g/L)	0.00142	0.00153	0.00161	0.00136	0.00148
Sodium (g/L)	0.94000	0.75000	0.96000	0.85000	0.88000

1 = Mbiabo Edere, 2 = Obio Usiere, 3 = Atan Onoyom, 4 = Okpo.

as described by Tel and Rao (1982). Data were collected from 10 randomly sampled plants in two middle rows on the same variables descried in the greenhouse experiment. Data collected were subjected to analysis of variance using MINITAB 15 statistical software. Means were separated using Duncan's New Multiple Range Test (DNMRT) at 5% level of probability.

3. Results and discussion

The physical and chemical properties of the samples collected from the communities are presented in Table 1. The texture varies from loamy sand to sandy loam. The soils are moderately acid in reaction. The organic carbon and total nitrogen contents of both the surface and sub-surface soils are low. The available P is rated medium for the soils. The exchangeable Ca, K and Na are low while Mg is rated moderate. Similarly, ECEC values are low but is rated high for Okpo soils (Table 1). However, the base saturation values are high as most values exceeded 60% in both soil layers. These are indicators of a poor acid sand soil typical of tropical humid rainforest zone as reported by earlier researches (Aiohu et al., 1998; Okigbo, 1990).

The pH of the urine varied from 8.90 to 9.20 with a mean value of 9.0 (Table 2). The total nitrogen, phosphorus, potassium and sodium concentration in the urine were 4.58, 0.26, 0.87 and 0.88 g/L, respectively, while the mean concentration of calcium and magnesium were 0.01618 and 0.00148 g/L, respectively. These findings agree with the values reported by other authors (Heinonen-Tanski et al., 2007; Kirchmann and Pettersson, 1995; Meinzinger and Oldenbrug, 2008). According to Sullivan and Grantham (1982) and Vinnerås and JÖnsson (2002), the composition of human urine varies from person to person and from region to region depending on his/her feeding habits, the amount of drinking water consumed, physical activities, body size and environmental factors. The people of Eniong Creek are mostly fishermen and provide an ample supply of animal protein to their families which could justify the high-N content of their urine.

Application of urine or inorganic fertilizer significantly ($P < 0.05$) increased okra leaf concentration of N, P and K in both communities relative to the control (Table 3). Application of 20,000 L/ha of urine had significantly ($P < 0.05$) the highest concentration of N, P and K. However, the concentration of leaf N and P in 15,000 L/ha urine plots were similar to the NPK fertilizer treated plots. The same trend was observed for leaf K concentration between 20,000 L/ha urine plots and inorganic fertilizer treated plots. This could be attributed to better uptake of these elements by plants with reduced loss through leaching. The okra leaf concentration of Ca and Mg were significantly ($P < 0.05$) increased with increase in application rate of urine compared with the control or NPK fertilizer treated plots (Table 3). The mineral fertilizer lacked Ca, Mg and other essential micro nutrients which have been reported to be contained in ample amount in urine by many authors (Karak and Bhattacharyya, 2011).

The results of the effect of urine and inorganic fertilizer application on okra growth attributes are shown in Table 4. For the greenhouse trials, application of urine and inorganic fertilizer significantly ($P < 0.05$) increased growth and leaf production compared with the control in soils of all the communities. In Mbiabo Edere soil, the greatest growth enhancement and leaf production were obtained with NPK fertilizer application. For Obio Usiere, Okpo, Ntan Obu and Atan Onoyom soils, urine application at 15,000 L and 20,000 L/ha significantly produced plants that were taller than pots treated with NPK 15:15:15 fertilizer. Leaf production was similar in pots treated with 15,000 L and 20,000 L/ha of urine compared with the NPK fertilizer treated pots (Table 4). For the field experiments, there were no significant differences

Table 3
Effect of urine and inorganic fertilizer on leaf nutrient composition of okra at Mbiabo Edere and Obio Usiere (field trials).

	Nutrient	Treatment				
		Control (no urine)	10,000 L/ha urine	15,000 L/ha urine	20,000 L/ha urine	400 kg NPK 15:15:15/ha
%N	Site A	2.48e[a]	3.58d	4.09b	4.66a	3.98c
	Site B	2.08d	3.22c	4.00b	4.25a	4.01b
%P	Site A	0.26d	0.36c	0.53b	0.69a	0.38c
	Site B	0.03d	0.30c	0.43b	0.56a	0.41b
%K	Site A	1.97d	2.40c	3.02b	3.74a	3.82a
	Site B	1.97d	2.18c	2.57b	3.10a	3.21a
%Ca	Site A	0.57d	0.88c	1.00b	1.30a	0.58d
	Site B	0.40d	0.69c	0.86b	0.96a	0.40d
%Mg	Site A	0.12d	0.17c	0.21b	0.33a	0.11e
	Site B	0.16d	0.19c	0.25b	0.40a	0.14e

Site A = Mbiabo Edere; site B = Obio Usiere.

[a] Means followed by the same letter within a row do not differ significantly from each other according to Duncan's New Multiple Range Test (DNMRT) at 5% level of probability.

Table 4
Effects of different levels of urine (U) and NPK fertilizer on the height and number of leaves/plants of okra.

Variable	Treatment				
	Control (no urine)	10,000 L/ha urine	15,000 L/ha urine	20,000 L/ha urine	400 kg NPK 15:15:15/ha
Plant height (cm/plant)					
Greenhouse					
1	28.33e[a]	39.00d	41.00c	47.33b	51.33a
2	25.00d	35.00c	42.00a	41.67a	38.33b
3	25.00d	30.00c	37.33a	38.00a	33.67b
4	21.00d	29.67c	32.00b	35.33a	29.00c
5	12.00d	18.33b	20.33a	20.67a	14.00c
Field					
A	59.00a	60.00a	71.00a	75.00a	58.67a
B	39.67e	43.67d	48.33c	51.67b	56.67a
Number of leaves//plant					
Greenhouse					
1	5.67e	7.00d	7.67c	8.33b	9.00a
2	4.33c	6.00b	6.33b	7.00a	7.33a
3	4.67d	6.33c	7.00ab	6.67b	7.33a
4	4.00d	5.00c	6.33a	5.67b	5.67b
5	3.67a	4.67a	4.67a	5.33a	4.33a
Field					
A	6.67d	7.67c	8.67b	9.33a	9.00ab
B	6.67c	767b	8.33a	8.67a	8.67a

1 = Mbiabo Edere, 2 = Obio Usiere, 3 = Okpo, 4 = Ntan Obu, 5 = Atan Onoyom; A = Mbiabo Edere, B = Obio Usiere.
[a] Means followed by the same letter within a row are not significantly different at 5% level of probability according to Duncan's New Multiple Range Test (DNMRT).

Table 5
Effects of different levels of urine (U) and NPK fertilizer on the shoot dry weight and number of pods/plants of okra.

Variable	Treatment				
	Control (no urine)	10,000 L/ha urine	15,000 L/ha urine	20,000 L/ha urine	400 kg NPK 15:15:15/ha
Shoot dry weight (g)/plant					
Greenhouse					
1	3.74d[a]	4.90c	5.02c	6.61a	6.04b
2	5.06d	6.74c	7.72b	9.02a	7.93b
3	3.74d	7.16c	8.04b	9.75a	10.20a
4	3.09e	4.57d	6.28c	8.60a	7.82b
5	1.20d	3.43b	3.48b	5.00a	2.50c
Field					
A	6.64e	7.20d	8.67c	10.04a	9.43b
B	5.97d	7.55c	8.88b	10.13a	8.66b
Number of pods//plant					
Greenhouse					
1	1.67a	1.67a	2.33a	2.33a	2.67a
2	1.00e	1.67d	2.33b	3.00a	2.00c
3	1.67a	2.00a	2.00a	2.67a	2.67a
4	1.00c	1.00c	2.00b	2.67a	2.00b
5	1.00c	1.00c	1.67b	2.00a	1.67b
Field					
A	2.00a	2.33a	2.00a	2.67a	2.33a
B	1.00a	1.43a	1.22a	2.00a	1.56a

1 = Mbiabo Edere, 2 = Obio Usiere, 3 = Okpo, 4 = Ntan Obu, 5 = Atan Onoyom; A = Mbiabo Edere, B = Obio Usiere
[a] Means followed by the same letter within a row are not significantly different at 5% level of probability according to Duncan's New Multiple Range Test (DNMRT).

Table 6
Effects of different levels of urine (U) and NPK fertilizer on the fresh pod weight of okra.

Variable	Treatment				
	Control (no urine)	10,000 L/ha urine	15,000 L/ha urine	20,000 L/ha urine	400 kg NPK 15:15:15/ha
Weight of fresh pods(g)/plant					
Greenhouse					
1	15.54d[a]	17.78c	20.10b	22.92a	19.92b
2	6.05e	21.58d	24.37b	26.33a	23.24c
3	12.67d	36.99c	41.51b	46.01a	45.67a
4	11.26e	16.51d	26.64c	33.02a	30.79b
5	4.06e	6.03d	8.78c	15.57a	10.39b
Field					
A	17.28e	20.36d	25.12c	34.72a	32.42b
B	15.16d	26.53c	27.31c	32.86a	30.56b

1 = Mbiabo Edere, 2 = Obio Usiere, 3 = Okpo, 4 = Ntan Obu, 5 = Atan Onoyom; A = Mbiabo Edere, B = Obio Usiere
[a] Means followed by the same letter within a row are not significantly different at 5% level of probability according to Duncan's New Multiple Range Test (DNMRT).

($P > 0.05$) among the treatments in plant height at Mbiabo Edere. However, the tallest plants were produced in plots treated with 15,000 L and 20,000 L/ha of urine. At Obio Usiere, urine and inorganic fertilizer application increased significantly ($P < 0.05$) all growth attributes of okra relative to control. Inorganic fertilizer application had similar effect on leaf production compared with urine at 15,000 L/ha and 20,000 L/ha (Table 4).

The effects of urine and inorganic fertilizer application on shoot dry matter accumulation and the number of pods set are presented in Table 5. Application of urine or inorganic fertilizer significantly ($P < 0.05$) enhanced shoot dry matter accumulation in okra in both greenhouse and field experiments compared with the control. However, 20,000 L/ha of urine produced significantly the highest shoot dry weight per plant. At Obio Usiere, 15,000 L/ha of urine had the same effect on okra shoot dry weight as the NPK fertilizer. For the greenhouse trials, similar numbers of pods were set in Mbiabo Edere and Okpo soils irrespective of the treatments. However, for soils from other locations, pod formation was significantly ($P < 0.05$) enhanced with urine or inorganic fertilizer application. The highest number of pods per plant was obtained with 20,000 L/ha of urine. Inorganic fertilizer had similar effect as urine applied at 15,000 L/ha (Table 5). For the field experiments, there were no significant ($P > 0.05$) differences among the treatments in pod setting.

The effects of urine and NPK 15:15:15 fertilizer application on fresh pod weight of okra are presented in Table 6. In both greenhouse and field trials with the exception of Okpo greenhouse test, fresh pod yield was significantly ($P < 0.05$) higher with 20,000 L/ha urine compared with other treatments. For the greenhouse study, 15,000 L/ha urine significantly ($P < 0.05$) out-yielded inorganic fertilizer treatment in Obio Usiere but had similar effect in Mbiabo Edere soil. However, in all the trials, urine or inorganic fertilizer treatments significantly ($P < 0.05$) enhanced pod yield relative to control. Generally, these trials have revealed that the growth and yield attributes of okra in 20,000 L urine/ha treated pots out performed NPK fertilizer treated plots. However, plots that received 15,000 L urine/ha had similar effect on growth and yield of okra like the NPK fertilized plots. From the chemical composition of urine and NPK fertilizer, it can be deduced that about 91.60 kg N/ha, 68.70 kg N/ha and 60.00 kg N/ha were released to the soil with application of 20,000 L urine, 15,000 L urine and 400 kg NPK (15:15:15) per hectare, respectively. Okra has a very high demand for N, Ca, K, Mg and low demand for P (Siemonsma and Kouame, 2004). For the growth and yield potentials of okra plant to be fully expressed, nutrients supply in good proportion and time are prerequisite (Akanbi et al., 2004). Thus, the presence of a vast array of essential elements (macro and micro) in human urine could justify the better fertilizing attributes of urine could justify the better fertilizing attributes of urine compared to mineral fertilizers as reported by many researchers (Bath, 2003; Heinonen-Tanski et al., 2007; Kirchmann and Pettersson, 1995; Simons and Clemens, 2004; Sundin, 1999). Human urine as an organic source of fertilizer releases plant nutrients faster than other sources (livestock/avian excreta, green manure, compost farmyard manure, etc.) commonly used by resource-poor farmers. This unique quality has been attributed to the presence of nutrient elements in urine in inorganic form (Bath, 2003; Kirchmann and Pettersson, 1995). Although the physico-chemical properties of the soil were not ascertained after harvest, it is possible that urine being alkaline could have acted as "fluid lime" by neutralizing the acidity of the soil and thus promoting okra growth. From the ecological sanitation point of view, urine diversion or separating toilets could be employed as a veritable tool in sanitizing the ecosystem and ensuring food security for a healthy population. It is worthy to note that the ECOSAN microbiology/parasitology research team had ascertained the complete die-off of enteric microorganisms with the urine storage period of two months. In conclusion, the trial has revealed the inert potentials of human urine as a good source of organic fertilizer (when used properly) that could be harnessed to boost the on-going organic farming programme in Nigeria.

4. Conclusions

The trial revealed that the soils of the five communities are mostly loamy sand to sandy loam in texture, acid in reaction and low in nutrient status. Human urine is strongly alkaline in reaction with moderate amount of nutrients (N, P, K, Mg, Ca and Na). Application of either urine or inorganic fertilizer significantly ($P < 0.05$) increased plant nutrient uptake compared with the control. Human urine applied at the rate of 20,000 L/ha in soils of Cross River State, with low nutrient status significantly increased the growth and yield of okra more than the inorganic fertilizer.

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