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Effect of Human Urine and Compost Tea on Soil Physical and Chemical Properties Case Study Rubirizi Marshland

Christian Shingiro[1, *], Guillaume Nyagatare[1], Hubert Hirwa[2], Uwingabire Solange[3]

[1]School of Agriculture Engineering and Environmental Management, College of Agriculture Animal Science and Veterinary Medicine, University of Rwanda, Nyagatare, Rwanda
[2]Department of Environmental Economics and Natural Resources Management, Faculty of Environmental Studies, University of Lay Adventists of Kigali (UNILAK), Kigali, Rwanda
[3]Department of Soil and Geological Sciences, College of Agriculture, University of Agriculture, Morogoro, Tanzania

Abstract

The high nitrogen levels in human urine are favorable for plant growth, however excessive use can also cause a buildup of salts in soil. This study has evaluated the effect of human urine at different dilution ratio and human urine combined with tea compost on soil physical and chemical properties. The experimental design consisted of pots where maize were planted in a randomized complete block design within five treatments and three replications: treatment 1/urine at 1:3 ratio (1L of urine in 3L of water), treatment2/urine at 1:5 ratio (1L of urine in 5L of water), treatment 3/urine at 1:3+TC (1L of urine, 1kg of compost and 3L of water), treatment 4/urine at 1:5+TC (1L of urine, 1kg of compost and 5L of water) and treatment 5/a control (tap water). The results showed that the electrical conductivity, sodium adsorption ratio for both soil and leached water significantly increased with decreasing in urine dilution ratio and increased with tea compost application, pH significantly increased with increasing in dilution ratio and tea compost application. Results also showed that they have been a significant increase in soil porosity, soil infiltration rate and aggregate stability with increasing in human urine and tea compost in the soil. The soil moisture characteristics curve showed that there were much available water at low pressure and less available water at high pressure for soils treated with human urine and tea compost compare to control. The analysis concluded that the application of human urine with or without tea compost increased significantly soil salinity to the soil; however soil structure was improved while combined with tea compost. Therefore salinity management measures should be included in urine fertilization programs. For example a well-adapted crop rotation system with salt-tolerant varieties and an adequate drainage system to remove leached salt.

Keywords

Soil Salinity, EC, Human Urine, Tea Compost, SAR, pH, Dilution Ratio

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1. Introduction

Worldwide salt accumulation on irrigated crop land is increasing and it is highly affecting agriculture productivity [1, 2]. However, in most of the low income countries commercial mineral fertilizers are expensive to be afforded by most of the farmers. Some concepts have been developed like the ecological sanitation (ECOSAN) which promotes the

* Corresponding author
E-mail address: shichriss@gmail.com (C. Shingiro)

use of human urine and composted faeces as an alternative source of fertilizer due to their elevated nutrients content in readily available form for plant [3]. Different researchers have tested human urine as an alternative source of fertilizer and most approved that human urine can improve plant growth and crop yield [4-9].

An adult person produces about 550L of urine per year [10]. 550L of urine are calculated to have 4.0 kilograms of nitrogen, 365 grams of phosphorus and 1 kg of potash [11]. Rwanda total population in 2012 was 12,501,156 [12]. If only 50% of total population of Rwanda start to collect urine, it equivalent about 25:2:6 thousand ton urea, phosphate and potash respectively which can totally fulfill the demand of chemical fertilizer in Rwanda and can also save the foreign currency needed to import these fertilizer.

Although human urine can supply nutrients to the crop, fresh urine contains salt bearing ions like Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-} and SO_4^{2-}, which can induce salinity and sodicity problem to the soil [4, 13]. Some of the beneficial physical properties associated to soil salinity are that some cations which are of small size like calcium and magnesium tend to bind together to the clay particle. These cations keep the soil flocculated, because they compete with other cations like sodium to occupy the same space on clay platelet. This means that as the amount of magnesium and calcium is increased, the amount of sodium is reduced, thus the sodium induced dispersion is also reduced [14, 4, 13].

Although calcium and magnesium can contribute to the flocculation of soil and improve soil aeration and water movement, crops grown on soil with excessive salinity level can suffer problems of high osmotic stress, nutrients imbalance, toxicities and reduction in crop productivity. On the other hand, when the sodium concentration exceeds a certain level of tolerance, the risk of soil sodicity can rise. One of the negative effects related to the increase of sodium level in soil is dispersion and swelling of clay particles. The force that cement soil particles become weak enough that the real soil structure becomes unstable and start to expand. However adding compost tea in the soil would enhance aggregation and stability of soil and thereby improving soil structure. Moreover tea compost improves the retention of plant nutrients and increases the soil biodiversity [15, 16]. Tea compost is also a source of plant nutrients, especially in the direct supply of N, P, S and K. Organic inputs from compost tea also enhance CEC particularly in sandy soils and reduce Al toxicity and P-fixation in strongly acid soils with oxide mineralogy [17].

Different studies have been carried out on the fertilizing value of human urine on different crops, yet little is known on the effect human urine with and without compost tea can have on soil physical and chemical properties especially in Rwanda. Therefore, this experiment was conducted to study the effect of human urine under different dilution ratio and its combination with compost tea on soil properties in Rubirizi marshland, Kicukiro district of Rwanda.

2. Materials and Methods

2.1. Study Area

This research was conducted at University of Rwanda experimental site located in Kicukiro district, Kanombe sector, Rubirizi cell (coordinates: 2°00'00"S and 30°08'00"E). The climate is of the type temperate tropical highland characterized by a long rainy season which lasts from about March to May, long dry season ranging from June to mid-September, short rain season which lasts from October to December and short dry season which lasts from January to March. The annual mean rainfall is estimated to 1,000 mm. The mean minimal and maximal temperature is estimated to 15°C and 26°C, respectively.

2.2. Experimental Design

The experimental design consisted of maize planted in pots in a randomized complete block design within five treatments and three replications; treatment 1/urine at 1:3 ratio (1L of urine in 3L of water), treatment2/urine at 1:5 ratio (1L of urine in 5L of water), treatment 3/urine at 1:3+TC (1L of urine, 1kg of compost and 3L of water), treatment 4/urine at 1:5+TC (1L of urine, 1kg of compost and 5L of water) and treatment 5/control (tap water). The size of each pot was 32cm top and bottom diameter and 40cm height which make $32dm^3$. The distance between pots was 1m and each was supported by two pairs of bricks spaced at 20cm. Pots were provided with a drainage system to drain water freely to improve soil aeration at the root zone. The drainage system was made by piercing and inserting small pipes of 30cm long and 2cm diameter covered with a sieve of 2mm at the end bottom of each pot to enhance water filtration. Drainage water was collected after the first and last irrigation for laboratory analysis.

2.3. Treatment Application

Human urine was collected from researcher's immediate family by constructing a diverting urine toilet. It was stored in the air-tight plastic container. Before application; urine was diluted to 1:3 ratio and 1:5 ratio using tap water. 2L of amendments was applied two times a week by using watering can around the crop.

Tea compost with urine was made once a week by mixing 2 kg of pure compost, 2L of human urine and 6 or 10L of water according to the ratio (1:3, 1:5) in a 50L plastic container. These mixtures were stored for two weeks in anaerobic condition before application; no other nutrients were supplied, before application to the crop it was filtrated using a 5mm sieve and were applied manually using watering can. The daily amount of water needed for irrigation was 4.4mm/day per pot (4.4L/m^2). Irrigation was done also with watering can and every day.

2.4. Sampling and Data Collection and Analysis Methods

Soil samples were collected before planting and at the end of the trial, almost two weeks after the last application of urine. Samples were taken with core samples for physical properties analysis (undisturbed) and in plastic bags for chemical properties analysis (disturbed).

Before analysis Samples were first air-dried and sieved through a stainless steel sieve of 2mm and 0.5mm. Initial samples for different amendments and samples at the end of the trial were analyzed to determine physical properties including; soil texture, bulk density, porosity, aggregate stability, infiltration rate and soil moisture characteristics. The chemical properties measured included; pH, Sodium adsorption ratio, electrical conductivity and nutrient concentrations of total nitrogen, available phosphorous, potassium, calcium, magnesium and sodium.

Soil texture was determined by using pipette method [18], Soil infiltration rate was determined using a hole method, wet aggregate stability was determined in laboratory by sieving with water and NaOH solution [19], Soil moisture characteristic was determined by using sandbox and by determining the gravimetric water content at different pressure, soil bulk density was determined by saturating soil samples then drying in over at 104°C for three days, soil porosity was calculated from bulk density and by calculations [19].

Soil and water salinity were determined by measuring the electrical conductivity and pH using electrical EC meter and electrical pH meter. Soil samples were first treated with distilled water for 24h to enhance particle distribution in the solution, before each reading EC and pH meter were calibrated with a standard solution of known conductivity and pH [18]. Sodium, calcium, magnesium and potassium were determined by filtrating with NH_4-acetate pH 7 four times in portions of 25ml and the reading done by using Atomic absorption spectrophotometer [18] and Sodium adsorption ratio was determined by calculation using:

$$\frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}+Mg^{2+}]}{2}}}$$

Total nitrogen was determined by using calorimetric method where 0.3g of 0.5mm was mineralised using H_2SO_4 and by digestion using distilled water and by using N_1solution then vortex and N_2 then vortex after 2hrs the solution was placed in UV cell for reading at the absorbency of 650mm [18].

The available phosphorus was determined by extraction the phosphorous in 5g of soil by adding P free charcoal shaking for 30min and by filtrating the solution, the color was developed by using Ammonium vanadate and molybdate the reading was done using UV cell at 430 mm absorbency [18].

2.5. Data Analysis

Data collected from this experiment was subjected to Analysis of variance (ANOVA) using Genstat discovery edition 6 Means was separated using Tukey test with an individual simultaneous confidence intervals. Significance level was 0.05.

3. Results

3.1. Initial Soil, Urine, Compost and Dam Water Characterization

Table 1 shows the chemical characterization of initial amendments used in this experiment. The electrical conductivity of urine was higher (19.67mS/cm); 2 times greater than that of compost (9.49mS/cm), 47 times more than tap water (0.42mS/cm) and 133 more than soil (0.147mS/cm). Sodium adsorption ratio was higher in pure human urine samples (8.53); 10 times more than tap water (0.82) and 110 times more than soil (0.07). The pH ranged from 6.1 in pure urine samples up to 8.99 in pure compost. The electrical conductivity and SAR decreased with increased in dilution ratio and it was the opposite for pH. Human urine contained appreciable amount of micro and macronutrients compare to soil and tap water. Nutrients concentrations were highly concentrated where human urine was at lower dilution ratio and where human urine was combined with tea compost (table 2).

Table 1. Initial chemical parameters of treatments.

Treatments	Electrical conductivity (mS/cm)	pH	SAR
Urine	19.67	6.1	8.53
Compost	9.49	8.99	6.64
Urine at 1:3	15.92	6.18	6.91
Urine at 1:5	12.7	6.25	6.08

Treatments	Electrical conductivity (mS/cm)	pH	SAR
Urine at 1:3+TC	17.92	8.5	7.67
Urine at 1:5+TC	14.7	8.56	7.77
Tap water	0.42	7.77	0.82
Soil	0.147	7.89	0.07

Table 2. Initial nutrients concentration for treatments.

Parameters	Urine (g/L)	Compost (mg/kg)	U1:3 (g/L)	U1:5 (g/L)	U1:3+TC (g/L)	U1:5+TC (g/L)	Tap water (mg/L)	Soil (mg/kg)
Tot N	3.99	57.78	3.48	3.15	3.49	3.17	0.66	0.14
AvailP	0.55	181	0.37	0.34	0.47	0.42	2.9	2.48
K	1.7	1406	1.53	1.47	1.59	1.55	15.1	0.73
Ca	0.06	151	0.06	0.06	0.07	0.07	24.1	4.3
Mg	0.04	86	0.03	0.03	0.05	0.05	3.3	3.1
Na	3.9	406	3.7	3.7	4.9	4.8	5.1	1.73

3.2. Effect of Human Urine and Compost Tea on Chemical Properties

The effect of human urine and compost tea on electrical conductivity, pH and sodium adsorption ratio were summarised in the table 3.

Table 3. Variation of chemical parameters of soil and leached water.

Treatments	Soil			Drainagewater		
	EC (µS/cm)	pH	SAR	EC (mS/cm)	pH	SAR
C	163.07±2.30 c	7.98±0.20 a	0.08±0.001 c	0.12±0.01 e	7.98±0.03 a	0.26±0.01 c
U1:3	871.33±35.73 b	6.56 ±0.29c	0.50±0.08 a	13.74±0.32 b	6.98±0.49 b	1.99±0.05 b
U1:3+TC	1 013.00±26.06 a	7.42±0.51 ab	0.54±0.03 a	15.80±0.56 a	7.30±0.21 ab	3.42±0.37 a
U1:5	751.93±39.80b	7.15±0.05 bc	0.38±0.02 b	6.53±0.30 d	7.22±0.08 b	1.72±0.09 b
U1:5+TC	857.18±9.85 b	7.66 ±0.24 ab	0.43±0.02 ab	8.12±0.71 c	7.52±0.15 ab	3.05±0.09 a

Mean value±standard deviation (SD); treatments with same letters are not significantly different (Tukey test, $p<0.05$). Soil EC ($p=0.001$), soil pH ($p=0.002$), soil SAR ($p<0.001$) and water EC ($p<0.001$), water pH ($p=0.009$), water SAR ($p<0.001$).

3.2.1. Electrical Conductivityand Sodium Adsorption Ratio

The results showed that soil EC and SAR varied from 163.07 to 1013.00µS/cm and 0.08 to 0.54 respectively, and that of leached water varied from 0.12 to 15.8mS/cm for EC and 0.26 to 3.42 for SAR. The highest EC and SAR value was observed on soil amended with amended with U1:3+TC whereas the lowest value was found in control. The EC of leached water were approximately 10 times more than the EC of soil and the SAR of leached water were approximately four times more than that of soil. These results implied that soil electrical conductivity and sodium adsorption ratio increased as amount of urine and tea compost fertilizers were increased to the soil, soil salinity and sodicity were decreased by increasing the dilution ratio in human urine. And much salt bearing ions which otherwise could build in the soil solution were removed by drainage system. The same results were found by [7] who reported an increase of EC and SAR with increase in human urine to the soil. These results could be attributed to the fact that human urine and tea compost used were inherently saline, high dosages of human urine and tea compost entailed higher amount of salts added to the cultivation substrate.

3.2.2. pH

For both soil and drainage water, the highest pH was found in control (7.98; 7.98 respectively) and the lowest pH in soil treated with U1:3 (6.56; 6.98 respectively). The pH of leached water was higher for U1:3 and U1:5 treatments compare to the same treatments in soil and were lower for U1:3+TC and U1:5+TC treatments in leached water tothose in soil.

The pH was decreased by increasing in human urine, and increased by increasing in compost tea. This is in agreement with [19], who reported an increase and decrease of soil pH on plots treated with tea compost and human urine respectively. The increase and decrease of soil pH could be attributed to fact that human urine used was slightly acidic and also by the fact that tea compost used in this experiment was alkaline.

3.2.3. Nutrients Concentration

Results showed a statistical significant difference among different treatments at ($p<0.05$) regarding to different nutrients concentration (table 4). The highest nutrients concentrations were found in soil treated with U1:3+TC and soil treated with U1:5+TC and the lowest nutrients were found in control. This implied that the concentration of different nutrients increased by decreasing in human urine dilution ration and by adding tea compost to the soil.

Table 4. Nutrient concentration of treatments at harvest.

Treatment	Total nitrogen (g/L)	Availablephosphorus (mg/kg)	Potassium (mg/kg)	Calcium (mg/kg)	Magnesium (mg/kg)	Sodium (mg/kg)
C	0.55±0.001 d	2.52±0.277 d	0.74±0.001 d	10.17±2.13 c	30.12±2.28b	1.95±0.04 e
U1:3	2.44±0.001 a	18.65±1.702 b	2.63±0.001 b	11.19±1.13 bc	31.84±1.51b	4.09±0.64 b
U1:3+TC	2.53±0.003 a	25.00±1.463 a	3.79±0.003 a	14.69±2.68 a	35.44±1.04a	4.86±0.28 a
U1:5	1.15±0.002 c	14.04±0.986 c	2.17±0.003 c	11.90±3.63 b	31.00±1.45b	3.14±0.20 d
U1:5+TC	1.40±0.003 b	22.30±2.723 ab	3.75±0.004 a	14.45±3.26 a	36.30±1.09a	3.65±0.19 c

Mean value ± standard deviation (SD); treatments with same letters are not significantly different (Tukey test, $p<0.05$). Total nitrogen ($p<0.001$), available phosphorus ($p<0.001$), potassium ($p<0.001$), calcium ($p<0.001$), magnesium ($p<0.001$), sodium ($p<0.001$).

3.3. Effect of Human Urine and Compost Tea on Soil Physical Properties

The table 5 summarize the effect of human urine and tea compost on soil infiltration rate, soil bulk density, soil porosity and soil aggregate stability. The textural class was sandy loam.

Table 5. Effect of urine and tea compost on some soil physical properties.

Treatment	Infiltration (mm/h)	Bulk Density	Porosity (%)	Aggregate stability
C	18.26±2.43 c	1.38±0.01	45.38±0.24 c	0.42±0.01
U1:3	23.25±3.52 ab	1.25±0.01	52.17±0.41 a	0.51±0.01
U1:3+TC	24.49±0.60a	1.22±0.01	52.97±0.10 a	0.52±0.01
U1:5	20.31±2.71 bc	1.28±0.01	50.26±0.24 b	0.47±0.01
U1:5+TC	21.87±0.71 ab	1.27±0.01	51.76±0.45 a	0.49±0.01

Mean value ± standard deviation (SD); treatments with same letters are not significantly different (Tukey test, $p<0.05$). Bulk density ($p=0.707$), porosity ($p<0.001$), infiltration ($p=0.002$), aggregate stability ($p=0.832$).

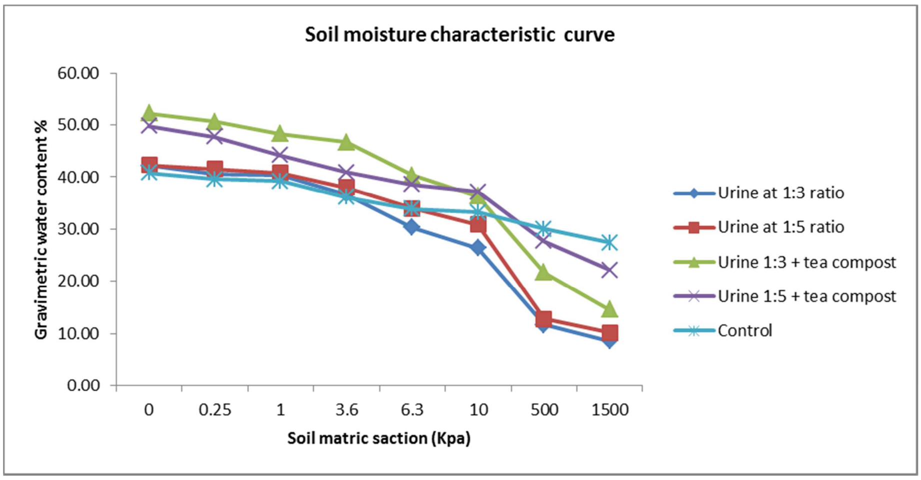

Figure 1. Soil moisture characteristic curve.

Results showed a statistically significant difference ($p<0.05$) for soil infiltration rate and soil porosity, no statistically significant differences were observed in aggregate stability and bulk density (table 5). Soil treated with U1:3+TC was found to have higher infiltration rate, soil porosity, aggregate stability and lower bulk density (24.49mm/h, 52.97%, 0.52, 1.22) and the lowest infiltration rate, soil porosity, aggregate stability and highest bulk density was found for control (18.26mm/h, 45.38%, 0.42, 1.38).

It was found from results that soil porosity, soil infiltration rate and aggregate stability were increased by applying human urine at lower dilution ratio and by applying human urine with compost tea.

This was due to the increased concentration of Ca^{2+} and Mg^{2+} in the soil solution which promoted clay particle aggregation by pushing adsorbed cations closer to the soil particles surface and keeping soil aggregates together.

Soil moisture characteristic curve.

The soil moisture characteristic curve below shows the gravimetric water content in relation with matric suction. It was observed that at low pressure near 0kpa soil treated with U1:3+TC and 1:5+TC holded much water compare to U1:3, U1:5 and the control, as the pressure increased soil treated with human urine with or without tea compost loosed water faster than the control. At high pressure, 1500kpa there were much water for control compare to other treatments. These implied that water content increased with increasing in human urine and tea compost and decreased with increasing in salinity level to the soil. This is explained by the fact that at high pressure high salinity levelcaused high osmotic stress for soil treated with human urine and compost tea compare to control and these soils need to be irrigated more frequently to prevent the problem of water stress for the plant.

4. Conclusions

After crop harvest soil salinity and sodicity were increased approximately five times more than the control and on a long period of time with continuous application of human urine and tea compost as liquid fertilizers the risk of soil salinity or sodicity could be a concern, therefore; it would be required to pay attention while fertilizing with human urine.

Some of the alternatives which could be developed to prevent the risk of soil salinity build up included; for example a well-adapted crop rotation system with salt-tolerant varieties and halophytic vegetables to reduce the potential risk of an eventual salt build up and an adequate drainage system to remove salt through leaching.

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