International Journal of Plant Science and Ecology
Vol. 6, No. 1, 2020, pp. 1-6
http://www.aiscience.org/journal/ijpse
ISSN: 2381-6996 (Print); ISSN: 2381-7003 (Online)

Effect of Human Urine and Compost Tea as Fertilizers for Maize, Beans and Cabbage Production in Rwanda, Rubirizi Marshland

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Abstract

Human urine fraction contains the major plants nutrients, with 80% of the Nitrogen (N), 55% of the Phosphorus (P) and 60% of the Potassium (K). Thus, urine has a potential to be reused in agriculture as a liquid fertilizer in order to reduce industrial fertilizer use which are expensive for most of the low income farmers. This study aimed at evaluating the effect of human urine on different crops. The experimental design consisted of three different crops: maize, beans and cabbages. Maize were planted in plastic pots, cabbages in sacs and beans in open field, all 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). Results showed that the number of leaves, plant height, plant leaves diameter, total plant weight and total grain weight were statistical significant different between treatments. Soil amended with U1:3+TC and U1:5+TC resulted in yield approximately twice higher than the control followed by U1:3 and U1:5. The increase in yield was due increased plant nutrients from human urine and the supplemental effect of tea compost to increase organic matter content, water holding capacity, plant diseases control. From this result it was concluded that the human urine with or without tea compost is effective to increase maize, beans and cabbages yield, however its application should be accompanied by soil salinity management techniques for its sustainable use.

Keywords

Tea Compost, Human Urine, Dilution Ratio, Beans, Maize, Cabbages

Received: October 26, 2019 / Accepted: January 8, 2020 / Published online: February 20, 2020

1. Introduction

Good agriculture relies on better agricultural techniques which increase soil fertility while minimizing soil degradation [1]. Current agricultural practices are intensifying to satisfy food demand for the overgrowing population, resulting in increasing nutrients depletion and loss of productivity in major agricultural lands across the world, and making nutrients input a necessity for crop production [2].

The joint use of both mineral and organic fertilizers is recommended in Rwanda [3]. However, their use is hampered by unaffordability to the average Rwandan farmer and scarcity on the local input market [3, 4]. In several parts of Rwanda, farmers are increasingly resorting to alternative low cost and easily available fertilizing material: human excreta (faeces and urine). Urine is a reasonable nutrient source [6, 11, 22]. The

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human body excretes around 550 litres per year for a person [7, 20, 21]. 550 litres of urine is calculated to have 4.0 kg of Nitrogen, 365 g of Phosphorus and 1 kg of potash [8, 23].

Rwanda total population in 2012 was 12,501,156 [7]. 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 fertilizers. In undiluted fresh human Urine, the following elements were found, nitrogen 7-9 g/L, phosphorus 0.20-0.21 g/L, Potassium 0.9-1.1g/L, Sulphur 0.17-0.22g/L, Calcium 13-16 mg/L and Magnesium 1.5-1.6 mg/L [17] and most of the Nitrogen in human urine is in a form suitable for plants [10]. Several studies concluded that human urine can have the same fertilizer effect as mineral fertilizer [11, 12, 5]. Compost tea is a liquid extract of solid compost incubated with or without a microbial food source to extract the soluble nutrients and plant beneficial microbes into the solution [13]. Compost tea has been reported to boost crop yield, soil biology, and disease suppression [14]. In a study performed on Brussel sprouts Radin et al. [15] demonstrated the potential of compost tea as a nutrients supplement to compost application. The nutrients supplied in compost tea are claimed to be a more readily available than solid compost's [16]. Also compost tea by increasing soil microorganism population and diversity to improve soil structure, water retention, rooting depth and plant growth [24, 22].

Therefore, the combination of human urine and tea compost cannot only increase the fertilizing potential of readily available fertilizing inputs, but can also prevent the degradation of soil structure associated with urine application [22]. Thus this combination holds good promises for most of the farmers in low income countries unable to rely on commercial mineral fertilizer to increase their harvest [10]. However, very little research has been carried out on the use and effect of human urine and tea compost as a source of plant nutrient in Rwanda. Hence, this study was conducted to compare effects of human urine at different dilution rates, with and without compost tea, on the growth and yield of maize, beans and cabbages.

The objectives of this research was to determine the effect of human urine and compost tea on maize, beans and cabbages, assess if there was any difference on yield for different dilution ratio. The results from this study would help to know which dilution ratio is the best, which crop reacts more positively to human urine and compost tea.

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 of latitude and 30° 08' 00" E of longitude). 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 at 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 three different crops, maize, beans and cabbages, submitted each to five fertilisation treatments and three replications in randomized complete block design. 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); treatment4: urine at 1:5+TC (1L of urine, 1kg of compost and 5L of water) and treatment 5: control (tap water). Maize were planted in plastic pots, cabbages in sacs and beans in open field. The size of each pot was 32cm top and bottom diameter and 40cm height which make 32dm^3 and 4m^2 for the open field and 30cm top and bottom diameter and 35cm height which make 31.5dm^3. The distance between pots was 1m and each was supported by two pairs of bricks spaced at 20 cm. 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 30 cm 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. Test Crop

Maize (*Zea Maize Saccharata*), bean (*Phaseolus vulgaris*) and cabbage (*Brassica oleraceacapitata*) were used as experimental crops. These are local varieties most used by farmers taking 100-140, 75-90, and 120-140 days from sowing to harvest, for maize, beans, and cabbages, respectively. Local fertilizer nutrients recommendation were 160-180 kg N/ha, 50 kg P/ha, 120-180 kg K/hafor maize; 100-120 kg N/ha, 30-65 kg P/ha, 50-96 kg K/ha for beans; and 180-250 kg N/ha, 70-90 kg P/ha and 190-200 kg K/ha for cabbage [4].

Before the experiment soil test was done to determine the nutrients status in soil. Amendments were applied two weeks (14 days) after sowing and were applied two times per week for the first eight weeks. Maize, beans and cabbages were harvested three weeks after the last amendment application.

2.4. Treatment Application

Human urine was collected from the researcher's immediate family by constructing a diverting urine toilet. It was stored in air-tight plastic containers of 32 dm^3. Before application; urine was diluted to 1:3 ratio and 1:5 ratio using tap water. 2L of diluted urine was applied around crops two times a week using watering can 1L in the morning and 1L in the afternoon. Compost tea with urine was made once a week by mixing 2kg of pure compost, 2L of human urine and 6 or 10 L of water according to the ratio (1:3, 1:5) in a 32dm^3plastic container. They were stored for two weeks in anaerobic condition before application their application was done twice a week. No other nutrients were supplied. Before application to the crop it was filtrated using a 5mm net and were applied manually using watering can. The daily amount of water applied for irrigation was 4,4mm/day per pot (4.4L/m^2). Irrigation was done also with watering can and every day a half in the morning and another half in the afternoon.

2.5. Sampling Procedure, 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 analysis. Before analysis Samples were first air-dried and sieved through a stainless steel sieve of 2 mm and 0.5 mm. Soil texture and nutrient concentration (total Nitrogen, available phosphorous, Potassium, Calcium, Magnesium and Sodium) were determined before and after treatment. Soil texture was determined by using pipette method [17] Sodium, Calcium, Magnesium and Potassium were determined by using Atomic absorption spectrophotometer [17]. Total Nitrogen was determined by using calorimetric method [17] The available Phosphorus was determined by using UV cell at 430 mm absorbency [17]. Data collected from this experiment was subjected to Analysis of variance (ANOVA) using Genstat discovery edition 13. Means was separated using Tukey test with an individual simultaneous confidence intervals. Significance level was 0.05.

2.6. Agronomic Parameters Assessment

Crop parameters tested included stem diameter measured using calliper, leave diameter and crop height measured using a steel tape, total plant weight and total grain weight measured using an electronic balance and number of leaves determined by counting.

3. Results and Discussions

3.1. Initial Nutrients Concentration for Treatments

Table 1 shows the initial nutrients characterization of the treatment formulations used in this experiment. Human urine contained higher amount of micro and macronutrients compared to tap water. Expectedly, treatments with compost tea; U1:3+TC and U1:5+TC were found to have high nutrients concentrations compare to the same treatment without compost tea and the highest nutrients concentrations were found in U1:3+TC (total Nitrogen (3.49 g/L), available Phosphorus (0.47 g/L), Potassium (1.59 g/L), Calcium (0.07 g/L), Magnesium (0.05 g/L) and Sodium (4.9 g/L)). Nutrients with lower dilution ratio were found to be rich in nutrients compare to those with high dilution ratio. However, the difference in nutrients content does not seen significant.

Table 1. Initial nutrients concentrations for amendments.

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)	U1:3+TC (g/L)	U1:5+TC (g/L)
Tot N	3.99	57.78	3.48	3.15	3.49	3.17	0.00066	0.00014
Avail P	0.55	181	0.37	0.34	0.47	0.42	0.002.9	0.00248
K	1.7	1406	1.53	1.47	1.59	1.55	0.0151	0.00073
Ca	0.06	151	0.06	0.06	0.07	0.07	0.0241	0.0043
Mg	0.04	86	0.03	0.03	0.05	0.05	0.0033	0.0031
Na	3.9	406	3.7	3.7	4.9	4.8	0.0051	0.00173

3.2. Nutrients Concentration After Harvest

Table 2. Nutrient concentrations of soil after harvest.

Treatment	Total Nitrogen (g/L)	Available Phosphorus (mg/kg)	Potassium (mg/kg)	Calcium (mg/kg)	Magnesium (mg/kg)	Sodium (mg/kg)
C	0.15 ± 0.001 d	2.52 ± 0.27 d	7.4±0.001 d	10.17 ± 2.13 c	30.12 ± 2.28 b	1.95 ± 0.04 e
U1:3	2.44 ± 0.001 a	180.65 ± 17.0 b	260.3±0.01 b	11.19 ± 1.13 bc	31.84 ± 1.51 b	4.09 ± 0.64 b
U1:3+TC	2.63 ± 0.003 a	250.00 ± 14.6 a	370.9 ±0.03 a	14.69 ± 2.68 a	35.44 ± 1.04 a	4.86 ± 0.28 a
U1:5	2.05 ± 0.002 c	140.04 ± 9.8 c	210.7±0.03 c	11.90 ± 3.63 b	31.00 ± 1.45 b	3.14 ± 0.20 d
U1:5+TC	2.30 ± 0.003 b	220.30 ± 7.2 ab	370.5 ±0.04 a	14.45 ± 3.26 a	36.30 ± 1.09 a	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 ($p<0.001$).

Results in table 2 showed that concentrations of all the nutrients measured increased significantly with addition of compost tea for the same urine dilution rate, with the exception of N which only significantly increased with compost tea at a higher dilution rate. Increasing urine dilution from 1:3 to 1:5 significantly reduced total N, available P, Ca, Mg, and Na. However, after inclusion of compost tea, the soil concentration for the same elements was not significantly reduced by the abovementioned dilution rate, except for N and Na. Compared to the control, all the treatments significantly increased the soil concentration in all measured elements except for Mg that was only increased by compost tea.

3.3. Effect of Human Urine and Compost tea on Crop Growth and Yield

3.3.1. Maize

Table 3. Agronomic parameters for maize after harvest.

Treatment	Number of leaves	Stem diameter (cm)	Plant height (m)	Leaves diameter (cm)	Total plant weight (g/pot)	Total grain weight (g/pot)
C	8.33 ± 0.58 b	1.16 ± 0.03 c	1.08 ± 0.08 c	1.53 ± 0.15 d	94.47 ± 4.91 d	10.97 ± 7.76 d
U1:3	10.67 ±0.54 ab	1.73 ±0.08 b	1.92 ± 0.08 ab	3.56 ± 0.26 ab	137.43±6.37 b	47.53 ± 2.25 b
U1:3+TC	11.66 ± 0.58 a	1.95 ± 0.08 a	2.15 ± 0.19 a	3.95 ± 0.11 a	158.23 ±4.56 a	59.37 ± 2.87 a
U1:5	11.00 ± 1.73 ab	1.71 ± 0.04 b	1.83 ± 0.04 b	3.05 ± 0.31 c	118.83± 9.11 c	33.30 ± 3.60 c
U1:5+TC	12.33± 0.58 a	1.85±0.06 ab	2.05 ±0.11 ab	3.30 ±0.57 bc	146.83±1.63 ab	45.50 ± 3.60 b

Mean value ± standard deviation (SD); treatments with same letters are not significantly different (Tukey test, $p<0.05$). Number of leaves ($p=0.011$), stem diameter ($p<0.001$), leaves diameter ($p<0.001$), Total plant weight ($p<0.001$), total grain weight ($p<0.001$), height ($p<0.001$).

Results from table 3 showed that compared to the control, application of urine significantly increased the performance of all agronomic parameters except the number of leaves. Increasing urine dilution from 1:3 to 1:5 significantly decreased leave diameter, plant weight, and grain weight without significantly affecting the number of leaves, stem diameter, or plant height. Compost tea increased the agronomic performance of maize in all urine dilution rates, however increase in performance was only significant for total plant weight and grain weight. These results are in agreements with Maggi et al., 2013 who reported the increase in crop yield by the use of human urine as a fertilizer for corn, potato and soybean. They also agree with Moustapha et al., 2013 who reported significant increase in maize height, shoot diameter and total plant weight relative to control resulting from urine application.

3.3.2. Beans

Table 4. Agronomic Parameters for Beans after Harvest.

Treatment	Number of leaves	Stem diameter	Plant height (m)	Leaves diameter	Total plant weight (g)	Total grain weight (g)
C	11.33 ±1.15 b	0.37 ± 0.06 c	0.94 ±0.05 c	5.13 ±0.21 b	61.00 ±1.80 c	20.27 ±5.44 d
U1:3	16.67 ±1.53 a	0.67±0.06 ab	1.24 ±0.08 b	7.13 ±0.32 a	95.37 ± 0.90 b	40.00 ±3.31 bc
U1:3+TC	16.67 ± 0.58 a	0.83±0.06 a	1.42 ±0.03 a	7.29 ±0.44 a	101.83 ±1.66 a	56.17 ±4.48 a
U1:5	15.00 ±1.00 a	0.57 ±0.06 b	1.22 ±0.03 b	6.63 ±0.75 a	93.20 ±0.61 b	33.03 ±14.33 c
U1:5+TC	15.33 ±1.53 a	0.77 ±0.12 a	1.39 ±0.03 a	6.93 ±0.38 a	96.30 ± 1.25 b	42.95 ±2.86 b

Mean value ± standard deviation (SD); treatments with same letters are not significantly different (Tukey test, $p<0.05$). Number of leaves ($p=0.004$), stem diameter ($p<0.001$), height ($p<0.001$), leaves diameter ($p<0.001$), total plant weight ($p<0.001$) and total grain weight ($p<0.001$).

Compared to the control, urine application significantly increased all the agronomic parameters of beans. However, urine dilution had not significant effect on those same parameters. Conversely, compost tea application significantly increased stem diameter, plant height, total plant weight and to grain weight, but not the number of leaves. These results are in agreements with those found by Maggi et al 2013 who reported significant yield increase in beans fertilized with human urine compare to other fertilizers.

3.3.3. Cabbage

Table 5. Agronomic Parameters for Cabbage After Harvest.

Treatment	Number of leaves	Stem diameter (cm)	Plant height (m)	Leaves diameter (cm)	Total plant weight (g)
C	11.6± 0.58 b	1.6± 0.05 b	0.16 ± 0.01 b	11.6±0.76 b	135± 4.36 c
U1:3	15.6 ± 1.15 a	2.2± 0.07 a	0.21 ± 0.01 a	17.5±0.87 b	123.3± 3.79 c
U1:3+TC	15.3 ± 1.53 a	2.1± 0.25 a	0.23 ± 0.01 a	17.00±0.50 a	193.3 ± 15.28 a
U1:5	12.3 ±1.53 ab	1.9±0.07 ab	0.20± 0.02 ab	15.7 ±0.63 a	120.± 5.00 c
U1:5+TC	12.7 ±1.15 ab	2.1± 0.12 a	0.24 ± 0.03 a	12.8±0.75 a	165.00 ± 5.0 b

Mean value ± standard deviation (SD); treatments with same letters are not significantly different (Tukey test, $p<0.05$). Number of leaves ($p=0.010$), stem diameter ($p=0.003$), height ($p=0.003$), leaves diameter ($p<0.001$), total plant weight ($p<0.001$) and total grain weight ($p<0.001$).

The results obtained for cabbage did not follow exactly the same trend noted for maize and beans: a significant increase in agronomic parameters resulting from urine application, with a tendency toward reduction in performance linked increase urine dilution rate, and significant improvement associated with compost tea. Cabbages fertilized with U1:3 and U1:5 were much more increased in volume (leaves diameter) that in weight due to increased Nitrogen in human urine. However other authors [10, 19, 21] reported faster growth and a high yield for urine fertilized cabbage.

4. Conclusion

Though N, P, K, Ca, Mg, and Na content in the different amendments (i.e., five treatments) did not seem significant, repeated application yielded significant differences in soil concentration in the same elements and crop yield after 60 days of application between the control and the other four treatments. Compared to the control, all the treatments significantly increased the soil concentration in all measured elements except for Mg that was only increased by compost tea. Increasing urine dilution from 1:3 to 1:5 significantly reduced total N, available P, Ca, Mg, and Na. However, after inclusion of compost tea, the soil concentration for the same elements was not significantly reduced by the abovementioned dilution rate, except for N and Na. Except for N, compost tea significantly increased the concentrations of nutrients measured for the same urine dilution rate. Urine application significantly increased maize and beans yields. The results were less conclusive for cabbage. Increasing urine dilution from 1:3 to 1:5 tended to decrease yield, though this was only significant for maize. Combination of compost tea with urine only increased significantly the yield of maize and beans yield.

The increase in crop yield is linked both to improved soil nutrients content in the case of urine application, and improved soil structure (combination of urine and compost tea). Therefore human urine and compost tea can be considered as liquid fertilizers and a potential fertilizer substitute for agricultural production.

Acknowledgements

The study could not have been carried out without the support of University of Rwanda, College of Agriculture Animal Science and Veterinary Medicine for their academic and laboratory support and my deepest appreciation also goes to Dr. Guillaume NYAGATARE for his assistance, advices and involvement to accomplish this research.

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