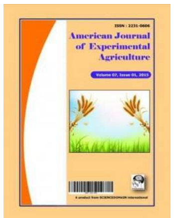

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Influence of Human Urine-compost Mixture on Some Soil Fertility Properties, Yield and Shelf-life of Tomato (*Solanum lycopersicon*)

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Authors' contributions

This work was carried out in collaboration among all authors. Author OOA designed the experiment, led and supervised the study. Authors COA and OEO were research assistants and participated in the field study and laboratory parts of the work. All authors participated in writing the manuscript, read and approved the final manuscript.

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ABSTRACT

Human urine, especially if combined with composts, could be a good source of fertilizer for improving soil fertility and ultimately, crop production. Thus, the focus of this study was to evaluate the influence of human urine-compost mixture on post-harvest soil fertility quality, yield and shelf-life of tomato (*Solanum lycopersicon*). The study had six fertilizer treatments: urine, compost, compost: urine - 1:2, compost: urine - 2:1, NPK 15-15-15 and the Control (no soil additive) laid in a Randomized Completely Block Design (RCBD), with four replicates. The experiment was conducted at the experimental field of the University of Ibadan, Nigeria. The treatments were applied at the rate of 90 kg K ha^{-1} and the effects on soil fertility status, number of fruits, fresh and dry weights, as well as shelf-life were observed, using tomato as the test crop. The urine treated soils had the highest (P<0.05) number of fruits (16.50 fruits $plant^{-1}$) at the end of the first planting. At the end of the second planting, urine treatment had the highest mean dry weight of 141 kg ha^{-1}

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tomato fruits, while NPK 15-15-15 resulted into the lowest yield (70 kg ha^{-1}). Thus, human urine-compost combinations 1:2 or 2:1 nitrogen are recommended as alternatives to mineral fertilizer (NPK 15-15-15) for tomato production, for improved yield, shelf-life and soil fertility.

Keywords: Solanum lycopersicon; human urine; fertilizer; soil fertility; wastes management.

1. INTRODUCTION

In several communities of the world, improper disposal of human urine continues to be a menace, contributing to environmental hazards. Compounds such as nitrogen dioxide (NO_2) and ammonia (NH_3) in this waste contaminates the environment and aquatic bodies, causing eutrophication and bad odours. However, human urine can be treated and converted to valuable agricultural uses. Human urine contains plant nutrients which are cheap and readily available, useful for improving soil fertility and increase food production [1-3]. According to Wolgast [4], the annual amount of human urine of one person corresponds to the amount of fertilizer needed to produce 250 kg of cereal that one person needs to consume per year; thus it is possible to have good quantity of human urine as fertilizer [5] for crop production. Human urine was successfully used to raise some crops like amaranths, celosia, lettuce, carrot, etc. [6-8]. Positive impact was also reported with maize [9-11]. Adewole et al. [12] elucidate that acceptability of urine as a fertilizer is a way of increasing farmers' gross margins.

Organic fertilizers are sourced from organic wastes which have several advantages compared to mineral fertilizers [13]. Examples of organic fertilizers are compost, green manure, animal manure, other agricultural wastes, human wastes (excreta, and urine), etc. There is an increasing research interest in the fertilizer value of human urine on the yield potentials of crops [11]. Thus, there was the need to evaluate the effects of human urine on tomato.

Tomato (*Solanum lycopersicon*) is one of the most important vegetable crops worldwide. It belongs to the family Solanaceae, with total world production of 159 million tonnes in a cultivated area of 4.7 million hectares and an average yield of 33.6 ton ha^{-1} [14]. Nigeria is ranked 16th on the global tomato production scale, and this accounts for 10.8% of Africa and 1.2% of total world production [15]. Human urine, compost and their mixtures have been found useful as sources of fertilizers, thus the main objective of this work was to evaluate the influence of human urine-compost mixture fertilizers on postharvest soil fertility quality, yield and shelf-life of tomato fruits.

2. MATERIALS AND METHODS

The study was carried out at the Department of Agronomy, University of Ibadan, Ibadan, Nigeria. The experimental plots (a long term trial with human urine fertilizer) had received the same fertilizer treatments continuously for the past six years prior to this experiment and planting was done twice. The soil was loamy sand based on USDA definition (www.ncrs.usda.gov/.../class), slightly acidic to slightly alkaline, low in nitrogen, moderate in organic carbon and potassium. The materials for the study included: tomatoes seeds (Roma VF), compost, NPK 15-15-15 mineral fertilizer, urine (harvested from Obafemi Awolowo Hall of residence, University of Ibadan, Ibadan, Nigeria and stored for 6 months in air tight plastic containers before use) [16]. The experiment was laid as a Randomized Completely Block Design (RCBD) with four replicates.

Table 1. Primary macronutrient composition of fertilizer treatments

Fertilizer source	Nutrient composition ($g\ kg^{-1}$)		
	N	**P**	**K**
Urine	4.8	0.1	8.7
Compost	17.5	11.0	8.7

2.1 Agronomic Study

The planting was done in two successions between May to September, 2012 and June to October, 2013 during the raining seasons (7th and 8th year of the study). Land clearing was done manually and this was followed by seedbed preparation. Each experimental plot was 2 m by 1 m with 0.5 m spacing in between the plots. There was a total of 24 experimental plots and land area of 79.75 m^2 (14.4 m X 5.5 m), transplanting of tomato seedlings was done at four weeks after sowing, at 60 cm X 40 cm spacing with twelve plants per plots. The fertilizer treatments were applied in split (twice) at the rate of 90 kg K ha[1] using spot application. The compost was applied one week before transplanting, while urine and NPK 15-15-15 mineral fertilizer was applied at two days before transplanting. The second application (45 kg K ha^{-1}) was done at the on-set of flowering of tomatoes, that is, two weeks after transplanting. Weeding was done manually as at when due with cutlass. Data were collected at 2 and 4 weeks after transplanting. Composite soil samples of six per plots were collected with soil auger at 0-15 cm depths for chemical and physical soil analysis. The soil samples were air-dried and sieved with 2 mm mesh for routine analysis. Particle size distribution was determined by hydrometer method [17], as cited by Tel and Hargarty [18], using sodium hexametaphosphate (calgon) as the dispersing agent. Soil pH was determined using pH meter in water (1:1) [19]. Organic carbon was determined using dichromate wet oxidation method [20] and value of organic matter was obtained by multiplying the Organic carbon value by a factor of 1.724. Total nitrogen was determined by macro Kjeldahl procedure [21]. Available phosphorus was determined by the method of Bray and Kurtz [22] and determined colourimetrically using Molybdenum blue Method, while K, Ca, and Mg were first extracted using neutral normal (NH_40Ac), thereafter K was determined by flame photometry, and Ca by spectrophotometry, using the atomic absorption spectrophotometer. Micronutrients (Mn, Fe and Cu) were extracted with Mehlich extractant and determined with Buck Scientific Atomic Absorption Spectrophotometer (AAS) model 210/211VGP.

Crop production parameters observed were number of fruits, fresh weight of yield (t ha^{-1}), dry weight (kg ha^{-1}), and shelf-life (number-of-days to 50% and 100% deterioration). The data obtained were analysed using analysis of variance (ANOVA α=0.05) [23]. Data on shelf-life (days) were analyzed based on Mondal's method [24].

3. RESULTS

3.1 Pre-planting Chemical Properties and the Effects of Applied Treatments on Post-planting Soil Nutrients

The pre-planting chemical properties of the soil revealed that at the first planting, the pH of the plots were slightly acidic to slightly alkaline: control (7.1), 100% compost (7.4), compost-urine 2:1 (7.3), compost-urine 1:2 (6.3), NPK 15-15-15 mineral fertilizer (7.2) and urine (7.1). At the end of the first planting, all the plots had their pH increased respectively. At the end of second planting, the pH of all the plots was reduced except the control. Moreover, the plots treated with 100% compost, compost-urine 2:1 and compost-urine 1:2 had higher margins in their reduction than others (Tables 1, 2).

The organic carbon of the experimental plots at the first planting ranged from medium to high (15 - 23.22 g kg^{-1}), with the control plots having the highest value (23.2 g kg^{-1}), closely followed by 100% compost plots (22 g kg^{-1}) and the lowest value (15 g kg^{-1}) was obtained from NPK 15-15-15 mineral fertilizer plots. All the treated plots were high in organic carbon except the NPK 15-15-15 mineral fertilizer plots, which was medium. At the end of first planting, all the treated plots had their soil organic matter reduced respectively; the least reduced plots were 100% compost (14 g kg^{-1}) and compost-urine 2:1 (13 g kg^{-1}). At the commencement of the second planting, the values of organic carbon ranged between 0.4-2.1 g kg^{-1}, with 100% compost plots having the highest value (2.1 g kg^{-1}) and followed by the urine plots (1.7 g kg^{-1}). At the end of the second planting, the plots treated with urine, compost-urine 1:2 and NPK 15-15-15 mineral fertilizer had their soil organic matter increased from 1.7 g kg^{-1} to 3.1 g kg^{-1}, 0.4 g kg^{-1} to 1.1 g kg^{-1} and 0.4 g kg^{-1} to 1.3 g kg^{-1} respectively (Tables 1, 2).

Similarly, the total nitrogen values of the plots at the commencement of the first planting ranged from 0.4-1.4 g kg^{-1}. The compost-urine 2:1 plots had the highest total nitrogen value (1.4 g kg^{-1}) and the lowest values in NPK 15-15-15 mineral fertilizer plots (0.4 g kg^{-1}) (Table 1). At the end of the first planting, all the plots had their total nitrogen increased respectively with the compost-urine 1:2 plots having the highest total nitrogen value (2.8 g kg^{-1}) which is above the critical range of 1.5 - 2.0 g kg^{-1} [13]. Moreover, at the commencement of the second planting, all the plots had low total nitrogen values (0.1 - 0.2 g kg^{-1}). However, at the end of the second planting, the compost-urine 1:2 plots had its total nitrogen value increased from 0.1 g kg^{-1} to 0.2 g kg^{-1}.

The exchangeable K values of the plots at the first planting ranged from medium to high (0.3 - 0.9 cmol kg^{-1}). All the treated plots had high exchangeable K values except compost-urine 1:2 (0.4 cmol kg^{-1}) plots and the control (0.3 cmol kg^{-1}) which were medium in exchangeable K. At the end of first planting, all the treated plots were medium in exchangeable K except NPK 15-15-15 mineral fertilizer plots (0.5 cmol kg^{-1}) which had high exchangeable K value. At the commencement of the second planting, all the treated plots were low in exchangeable K. At the end of second planting, the plots treated with 100% compost (0.5 cmol kg^{-1}) was high in exchangeable K, while compost-urine 2:1 (0.3 cmol kg^{-1}) and compost-urine 1:2 (0.4 cmol kg^{-1}) plots had medium exchangeable K.

At the first planting, extractible Fe in the experimental plots was at medium range with values of 60-105 mg kg^{-1}. The plots treated with 100% compost had the highest Fe value (105 mg kg^{-1}) followed by the compost-urine 2:1 plots (98 mg kg^{-1}) while compost-urine 1:2 plots had the lowest extractible Fe values (60 mg kg^{-1}). At the end of the first planting100% compost had the highest extractible Fe value (706 mg kg^{-1}) followed by the compost-urine 2:1 plots (698 mg kg^{-1}) while the urine plots (545 mg kg^{-1}) had the lowest extractible Fe value. At the commencement of the second planting, the extractible Fe values ranged from 72 - 105 mg kg^{-1}, with the urine plots having the highest value (105 mg kg^{-1}) and compost-urine 2:1 plots having the lowest value (72 mg kg^{-1}). At the end of the second planting, NPK 15-15-15 mineral fertilizer plots (242 mg kg^{-1}) had the highest extractible Fe value while the control plots (100 mg kg^{-1}) was the lowest.

At the commencement of the first planting, extractible Mn content of the experimental plots ranged within low to medium (58 – 104 mg kg^{-1}). The control plots had the highest extractible Mn value (104 mg kg^{-1}), while compost-urine 1:2 plots had the lowest extractible Mn value (58 mg kg^{-1}). At the end of the first planting, 100% compost (578 mg kg^{-1}) had the highest extractible Mn value, while compost-urine 1:2 plots had the lowest extractible Mn value (379 mg kg^{-1}). At the commencement of the second planting, compost-urine 1:2 plots (84 mg kg^{-1}) had the highest extractible Mn value, while the control plots had the lowest value (71 mg kg^{-1}).

3.2 Response of Tomato to Urine and Its Compost Mixtures

The result of the yield parameters revealed that the plants performed better with organic fertilizers than the NPK 15-15-15 mineral fertilizer. At the end of the first planting, the urine treatment produced significantly higher (P<0.05) number of fruits (16.50/plant) than NPK 15-15-15 mineral fertilizer, as well as the control treatment, the least number of fruits (3.25/plant) was recorded in the control treatment. At the end of

Table 2. Pre-planting chemical properties of the soil during 2012 and 2013

Treatments	pH (1:1)	O.C	N	P	K	Ca	Fe	Mn	Cu
		g kg^{-1}		$mgkg^{-1}$	$cmolkg^{-1}$		$mgkg^{-1}$		
1st Planting (2012)									
Control	7.1	23	0.5	21	0.3	3.1	97	104	1
100%C	7.4	22	1.2	24	0.9	2.8	105	97	1
C:U - 2:1	7.3	19	1.4	17	0.6	2.7	98	87	1
C:U - 1:2	7.3	19	0.8	19	0.4	2.1	60	58	0
NPK	6.3	15	0.4	14	0.7	2.8	88	95	2
Urine	7.2	21	1.2	21	0.6	2.6	90	95	1
Mean	7.1	20	0.9	19	0.6	2.7	90	89	1
SD	0.40	2.86	0.41	4	0.2	0.3	16	16	1
2nd Planting (2013)									
Control	7.0	1.3	0.1	27	0.2	2.9	90	71	2
100%C	7.1	2.1	0.1	36	0.2	4.9	95	81	2
C:U - 2:1	6.9	1.3	0.1	15	0.1	4.4	72	82	1
C:U - 1:2	6.6	0.4	0.1	20	0.2	3.8	95	84	2
NPK	6.7	0.4	0.1	16	0.2	2.9	85	79	2
Urine	6.6	1.7	0.2	24	0.1	3.1	105	78	2
Mean	6.8	1.20	0.12	23	0.2	3.7	90	79	2
SD	0.2	0.69	0.04	8	0.1	0.8	11	5	0

Legend: C = compost; U = urine; C:U = compost-urine ratio, NPK = NPK 15-15-15 mineral fertilizer, SD: Standard deviation the second planting, compost-urine 2:1 plots had significantly higher number of fruits (17.4/plant) than other treatments, while the control and NPK 15-15-15 treatments resulted into the least (Fig. 1).

Similarly, at the end of the first planting, the compost-urine 1:2 treatment resulted in the significantly higher (P<0.05) mean dry weight (834 kg ha^{-1}) than other treatments, while the least (149 kg ha^{-1}), was recorded in the control plots (no soil additive applied). Although not significantly better than the compost-urine mixtures, the urine treated plots had the highest mean dry fruit weight (142 kg ha^{-1}) at the end of second planting. The least dry fruit weight (25 kg ha^{-1}) was recorded in NPK 15-15-15 mineral fertilizer plots (Fig. 3).

At the end of the first planting, compost-urine 2:1 treated plots had significantly higher (P<0.05) mean fresh weight (13 t ha^{-1}) than others treatments, although, this was not significantly different from that of compost-urine 1:2 plots. At the end of the second planting, compost-urine 1:2 treated plots had significantly higher fresh fruit weight (1.8 t ha^{-1}) that was not significantly different from that of urine treated plots, while the least mean fresh fruit weight was recorded by crops treated with NPK 15-15-15 mineral fertilizer (0.5 t ha^{-1}) (Fig. 2).

The results of the effects of fertilizer treatments on shelf-life of tomato fruits is shown in Fig. 5. At days-to-50% deterioration, the treatments with 100 % compost and compost-urine 2:1 (37 days) treatment performed better than NPK 15-15-15 mineral fertilizer (13 days) treatment and the control (11 days) at the first planting (Fig. 4). A similar trend was recorded at the second planting (Fig. 5).

4. DISCUSSION

Generally, the compost and compost-urine 1:2 fertilizer treatments showed better residual soil fertility status compared to other treatments based on the soil chemical status analysed in this investigation. This better fertility status could be due to the gradual decomposing effect of the compost and its ability to improve soil fertility over a period of time, as is the general case with organic matter [4]. The result is also an indication that compost could serve as a storehouse for essential nutrients for crops. There was an increase in organic carbon and nitrogen of the some of the experimental plots, which in many cases could be associated with the increase in microbial activities due to the applied organic fertilizers [25]. Although, the pH of all the soils at the end of the first planting were within the safe range of 5.5 - 7.0 [26], however, this was not the case at the end of the second planting.

Table 3. Post-planting chemical properties of the soil during 2012 and 2013

Treatments	pH (1:1)	O.C	N	P	K	Ca	Fe	Mn	Cu
		g kg^{-1}		$mgkg^{-1}$	cmolkg^{-1}			$mgkg^{-1}$	
1st Planting (2012)									
Control	6.6	11.6	2.2	36	0.3	3.7	568	467	5
100%C	6.5	14.3	1.9	37	0.4	3.5	706	578	5
C:U - 2:1	6.6	12.8	2.2	34	0.4	3.3	698	479	6
C:U - 1:2	6.4	11.3	2.8	24	0.3	2.4	613	379	4
NPK	6.5	10.2	2.1	33	0.5	3.2	640	516	5
Urine	6.5	9.9	1.7	31	0.3	3.7	545	483	4
Mean	6.5	11.7	2.2	33	0.4	3.3	628	484	5
SD	0.1	1.7	0.4	5	0.1	0.5	66	65	1
2nd Planting (2013)									
Control	7.0	1.6	0.1	30	0.2	4.4	100	77	1
100%C	7.4	1.6	0.1	48	0.5	11.0	214	90	1
C:U - 2:1	7.3	1.1	0.1	28	0.3	4.1	152	88	1
C:U - 1:2	7.1	1.1	0.2	28	0.4	3.9	149	87	1
NPK	6.9	1.3	0.1	38	0.2	11.7	242	95	1
Urine	6.8	3.1	0.1	51	0.2	10.7	175	105	2
Mean	7.1	1.6	0.1	37	0.3	7.6	172	90	1
SD	0.2	0.8	0.0	10	0.1	3.9	51	9	0

Legend: C =compost; U = urine; C:U = compost-urine ratio, NPK = NPK 15-15-15 mineral fertilizer; SD: standard deviation

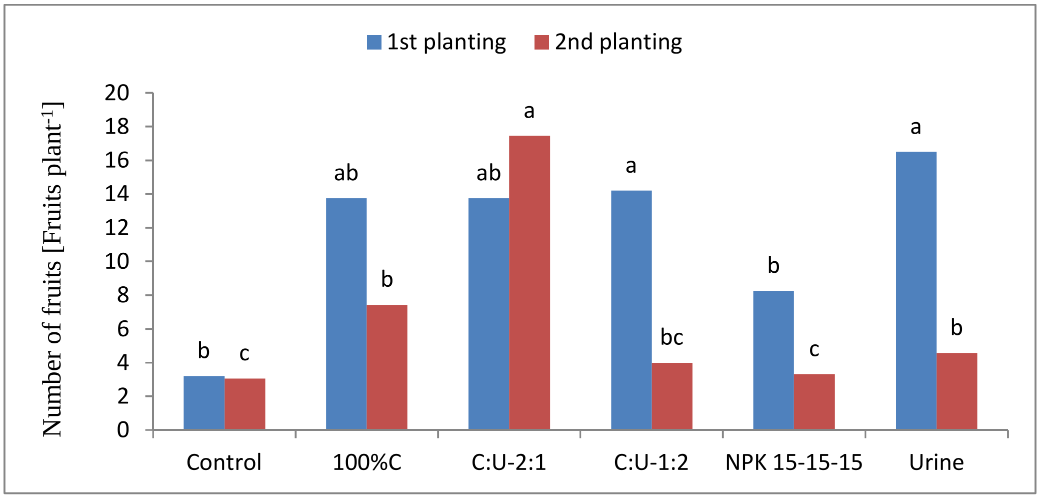

Fig. 1. Effects of the treatments on number of fruits
Legend: C =compost; U = urine; C:U = compost-urine ratio, NPK = NPK 15-15-15 mineral fertilizer
Means with same alphabet are not significantly different at p<0.05

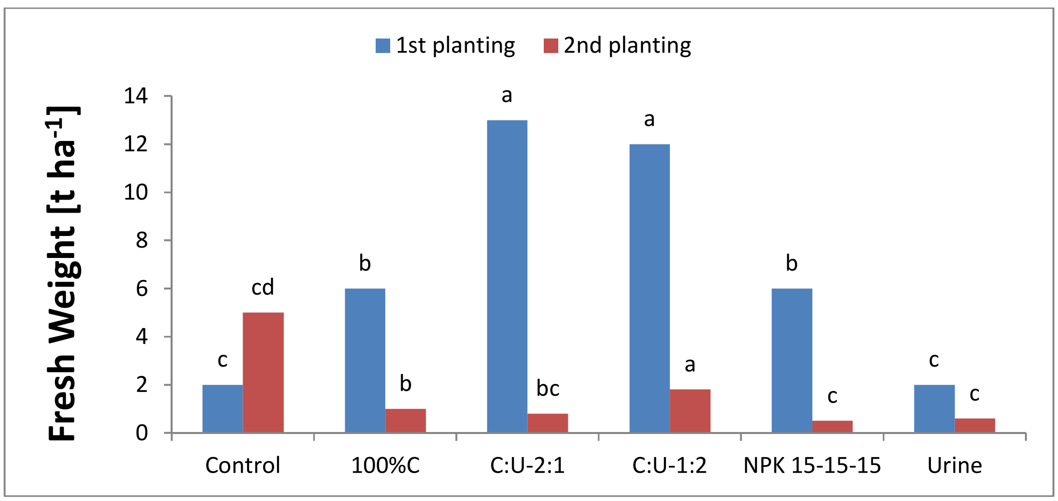

Fig. 2. Effect of the treatments on fresh weight of tomatoes
Legend: C =compost; U = urine; C:U = compost-urine ratio, NPK = NPK 15-15-15 mineral fertilizer
Means with same alphabet are not significantly different at p<0.05

The average pH of the soil at the second planting was basic; especially with the compost and its urine mixtures. This could be due to the strength of these organic fertilizers to buffer soil pH during tropical raining season, when the soil could be more acidic, due to leaching of bases.

The results indicated that the application of the compost-urine 1:2 resulted in the better dry weight of fruits in the first planting. Although, the yields during the second planting were generally low, due to bad weather (too much rain) and disease attack (powdery mildew), however, compost-urine 1:2 treatments resulted into better fresh weight of fruits during that planting. This is in agreement with the findings of Nansabuga, [27] and AdeOluwa and Cofie [6], who reported that human urine increased yields of some crops more than mineral fertilizers, and also in Finland [28] where cabbage grown with human urine performed better than those from conventional fertilizers. Similarly, the fruit yield (13 t ha^{-1}) at the first planting was higher than NPK 15-15-15 mineral fertilizer (6 t ha^{-1}) and the average yield of tomatoes (10 t ha^{-1}) [29] in the southwest, Nigeria. The better performance of urine and urine-compost mixtures compared to the mineral fertilizer corroborates previous experiments carried out by AdeOluwa and Sobamowo [7]. This indicates that the use of compost-urine mixtures as fertilizers can improve crop productivity.

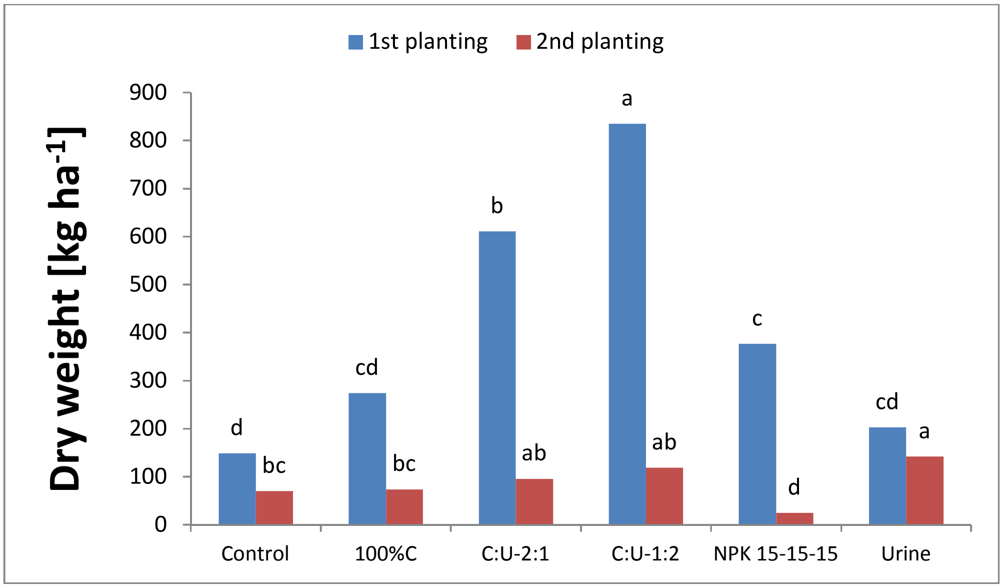

Fig. 3. Effect of the treatments on the dry weight of tomatoes
Legend: C =compost; U = urine; C:U = compost-urine ratio, NPK = NPK 15-15-15 mineral fertilizer
Means with same alphabet are not significantly different at p<0.05

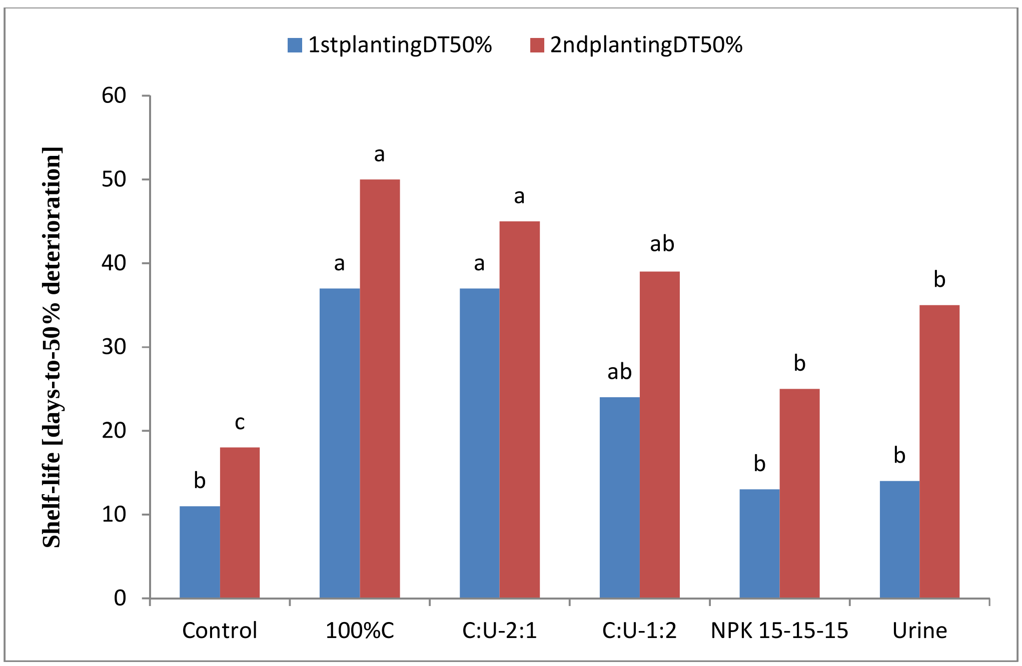

Fig. 4. Effects of the treatments on the shelf-life of tomato fruits after harvest
Legend: C =compost; U = urine; C:U = compost-urine ratio, NPK = NPK 15-15-15 mineral fertilizer
Means with same alphabet are not significantly different at p<0.05

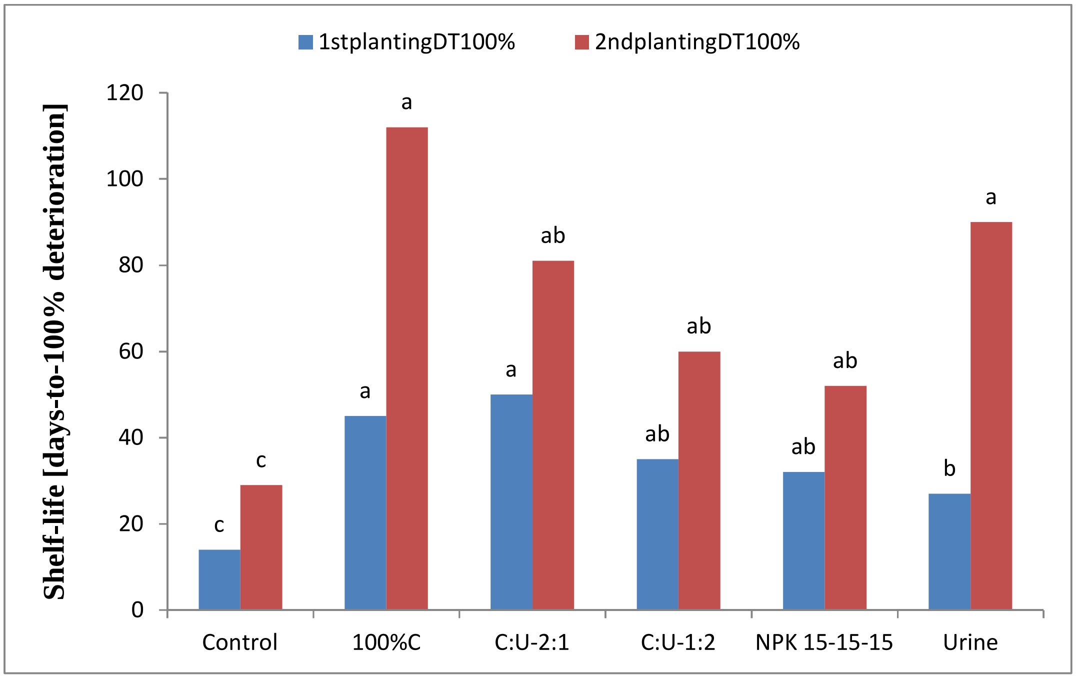

Fig. 5. Effects of the treatments on the shelf-life of tomato fruits after harvest

Legend: C =compost; U = urine; C:U = compost-urine ratio, NPK = NPK 15-15-15 mineral fertilizer
Means with same alphabet are not significantly different at p<0.05

Similarly, the compost and compost-urine 2:1 treatments had better influence on the shelf-life (days-50%-to-deterioration) of the fresh tomato fruits compared to NPK 15-15-15 mineral fertilizer. This result could be due to better dry matter accumulation effect on the tomato fruits [30]. Similarly, this could be due to better bio-availability of nutrients supplied by the organic fertilizers [31], compared to NPK 15-15-15 mineral fertilizer. Usually nitrogen in organic fertilizers is less bio-available; compared to mineral fertilizers. During rainy seasons, bio-available nutrients in soils could be easily washed away before the plants take them up. Thus, the human urine-compost mixtures could be better in term of sustainable nutrient management for crop production.

In summary, the results of this research revealed that compost and urine-compost mixtures could be excellent materials for improving soil fertility, yield of tomatoes and its shelf-life.

5. CONCLUSION

The results of this experiment revealed that human urine could be a good fertilizer for producing tomatoes in terms of soil fertility and shelf-life improvement. Moreover, if the compost is combined with urine nitrogen, the effects are better. Consistently, the compost and urine-compost mixtures performed better than the NPK 15-15-15 mineral fertilizer. This is an indication that if human urine is properly harvested and treated, it could be a valuable fertilizer. Thus, the use of compost or compost + urine N mixture is recommended for production of tomatoes. Urine alone could also be used when there is no compost to mix it.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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