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Urine as an alternative fertilizer in agriculture: Effects in amaranths (*Amaranthus caudatus*) production

O.O. AdeOluwa[1]* and O. Cofie[2]

[1]Department of Agronomy, University of Ibadan, Ibadan, Nigeria.
[2]International Water Management Institute, Accra, Ghana.
*Corresponding author: adeoluwaoo@yahoo.com

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Abstract

Crop production in most developing countries is faced with a dearth of resources for optimum production of which fertilizer is one. The use of human urine as well as its mixture with compost are potential solutions to this problem. Thus, this report investigated the influence of human urine and its combination with compost on yield and soil quality of land under green amaranths (*Amaranthus caudatus*). This study involved a field experiment to determine the response of green amaranths to the application of 100% urine, 2/3 urine N + 1/3 compost N, 100% compost N, NPK (15:15:15) at the rate of 100 kg N ha^{-1} and control with no fertilizer treatment using farmers' participatory approach. The vegetables produced from the experimental treatments were analyzed in the laboratory for pathogenic microbial risk as well as effects of the fertilizer on nutrient status of the experimental soils (before and after planting). Perception of farmers and consumers in the study area regarding use of urine as fertilizer for vegetable production was investigated with the aid of a structured questionnaire. The result of this investigation revealed that 100% urine resulted in 58.17 t ha^{-1} total plant yield, while NPK 15:15:15 gave 34.34 t ha^{-1} total plant yield in the two plantings. Microbial analysis of edible portion of vegetable from plot fertilized with urine did not reveal any significantly different pathological contamination compared to other fertilizer treatments used in this investigation. Urine treatment improved soil nutrient exchangeable cations and acidity. The perception study revealed that respondents perceived urine to be a good agricultural input that could be used as a fertilizer in vegetable crop production and there was no strong cultural norm that would prevent them using it for crop production. Vegetable consumers would also buy vegetable crops grown with urine if they are well informed about its safety for crop production. Since the use of urine as fertilizer for crop production improved amaranth's yield and did not show any negative implication on soil environment, human urine seems to have good potential both in crop yield and acceptability by farmers and consumers.

Key words: human urine, amaranths, fertilizer, perception, nutrient status, crop yield

Introduction

Rapid urbanization will result in the generation of more wastes in cities including human urine which has been found to be a good fertilizer for crop production[1,2]. However, economic returns and microbial contamination as well as acceptability are issues of concern.

Physiological measurement shows that an adult in a year excretes via urine 2.5–4.3 kg N, 0.7–1.0 kg P and 0.9–1.0 kg K. This is higher than levels excreted via feces and represents 60–90% of the plant N, P and K ingested, which can be retrieved in solution[3]. Although excellent performance of human urine as a fertilizer in crop yield has been reported[4–6], there is a need to quantify financial returns from urine fertilizer.

It has been reported that fresh human urine is sterile in the bladder[7]. *Leptospira interrogans*, *Salmonella typhi, Salmonella paratyphi* and *Schistosoma haematobium* are pathogens traditionally known to be excreted in urine[8]. The possibility of transmitting these pathogens via urine as fertilizer in developed countries is negligible[7]. Where human wastes such as urine can improve agricultural productivity, independently of their microbial characteristics, they can contribute to the nutritional status of the population, thus improving public health[4]. However, it is necessary to investigate whether the same will hold in a

Figure 1. Satellite imagery of the project area, Mokola, Ibadan, Nigeria. The arrow points to the experimental plot.

developing country such as Nigeria with less strict environmental health policies. Although the use of urine in agriculture is not new[9], attitudes of farmers and consumers to acceptability in crop production is not certain.

Richert *et al.*[10] reported that dissemination and knowledge development on urine as a fertilizer are best gained through local demonstration experiments involving organizations that work with small-scale farmers and local communities, as well as local research organizations. Thus, this report presents an investigation of the effects of human urine in comparison with other fertilizer materials on the yield of amaranths (*Amaranthus caudatus*) on small-scale farms. Post-production analysis of soil nutrient and crop pathogen concentration was done as well as the study of the perception of farmers and consumers to the use of urine in crop production.

Materials and Methods

This study involved a field experiment to determine the response of green amaranths (*A. caudatus*) to the application of urine and other fertilizer sources using a participatory approach. The vegetables produced from the experimental treatments were analyzed in the laboratory for pathogenic microbial risk as well as the effects of the fertilizer on the nutrient status of the experimental soils before and after planting. Perceptions of farmers and consumers in the study area regarding use of urine as fertilizer for vegetable production was investigated with the aid of a structured questionnaire, participatory field planting/demonstration and laboratory analyses.

This investigation was carried out between December 2008 and August 2009. The study was carried out at the Mokola-Army Barracks of Ibadan, North West Local Government, Oyo State, Nigeria. The local government owns a large area of land with a population of about 147,918 according to the 1991 Census. Average annual rainfall is 1280 mm with a bimodal pattern. Minimum and maximum temperatures range from 12 to 30°C and 28 to 34°C, respectively.

Commercial vegetable production in urban centers in Nigeria is dependent on cultivation of institutional land (such as the Army Barracks). There are up to five such vegetable farming communities within urban and peri-urban Ibadan, but the project community was selected due to the high level of cooperation from the farming community. Farmers in this area are mostly men from different ethnic groups of Nigeria. An aerial photograph of the study location is shown in Figure 1.

Agronomic study

The planting experiment involved cultivation of green amaranths with fertilizer treatments at a rate of 100 kg N ha^{-1} using 100% urine, 2/3 urine N + 1/3 compost N, 100% compost N, NPK (15:15:15) and control with no fertilizer treatment. Urine was collected from a male hostel at the University of Ibadan and some households in Ibadan, while the compost is a commercial product. The collected urine was stored under airtight conditions for a month. The total land area is 63 cm^2 (average size of small-holding farm in the study area) made up of 20 beds of 2 m × 1 m with fertilizer treatments replicated four times. Plant population was at a rate of 1.8 million plants ha^{-1}. The experiment was laid in a randomized complete block design. Planting was done in two successions; first planting with fertilizer application and second planting without fertilizer application (residual). Yield parameters observed were subjected to statistical

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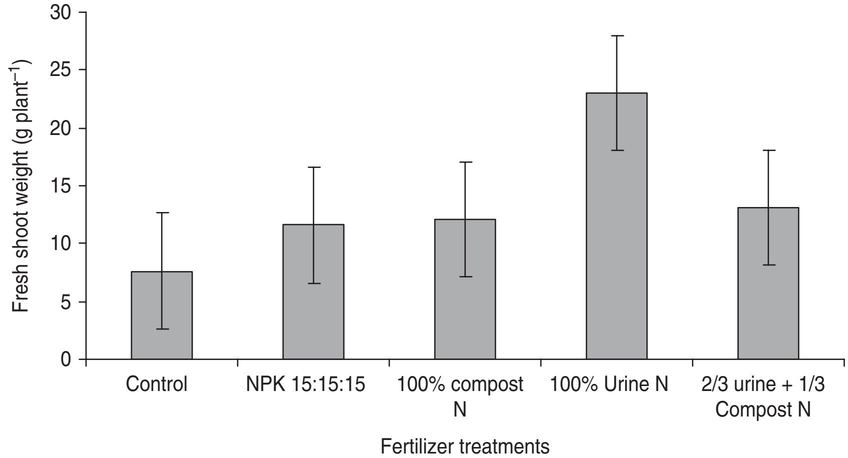

Figure 2. Effects of fertilizer treatments on fresh shoot weight yield of green amaranths at 4 weeks after the first planting.

analysis using least significant difference to separate means.

Soil samples were collected at depths of 0–15 cm using a soil auger before the experiment began. The physical and chemical analysis of the experimental soils was carried out before the treatments were added to the soil. The soil was air-dried and sieved using a 2 mm sieve. Soil particle analysis was determined by mechanical analysis, using the hydrometer method[11]. Soil pH was determined in water and KCl (both in ratio 1:1) using a pH meter with a glass electrode. Total nitrogen was determined using the macro-Kjeldahl procedure[12], while organic carbon was determined by using the wet oxidation method[13]. Organic matter content was determined by multiplying the organic carbon content by 1.74, while available phosphorus was determined by using the Bray1 method[14]. Exchangeable potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) were extracted with 1 N ammonium acetate. The concentration of K, Ca and Na in the filtrate was determined using a flame photometer, while Mg was determined using a Perkins-Elmer atomic absorption spectrophotometer. Exchangeable acidity was determined by means of the titration method and effective cation exchange capacity was determined by summation of exchangeable bases. Extractible copper, zinc, iron and manganese were extracted with EDTA and determined with an atomic absorption spectrophotometer.

Microbial analysis

The microbial analysis was performed on both main and residual plantings of green amaranths from the fertilizer trials on the field. Vegetable samples were selected randomly and taken to the laboratory in sealed envelopes to prevent contamination. An edible portion of the crop from each treatment was homogenized and the fluid extracted and serially diluted to obtain a 10^{-3} dilution factor using the ten-fold dilution method using sterilized nutrient agar for the isolation of aerobes and sterilized MacConkey agar was used for isolation of the coliforms/enterobacteria.

Perception of farmers and consumers on use of urine as fertilizer

Data were collected using the interviewer-administered questionnaires to obtain information from both the farmers working on the vegetable farm and the household members living in the barracks on socio-demographic characteristics, hygiene and sanitation practices and method of waste disposal. A total of 161 respondents were randomly interviewed for the perception study, of which 60 were farmers and the remaining 101 were consumers or retailers. A structured questionnaire was used to collect data. The interview schedule was conducted on a face-to-face basis with the respondents, while those who could fill in the questionnaires were given the opportunity to do so, with little or no assistance.

Results

The objectives of this project were to investigate the influence of human urine and its compost mixture on the yield of amaranths (*A. caudatus*), assess their impact on soil and crop quality as well as attitudes of farmers and consumers toward the use of urine in crop production.

Response of amaranths to urine, municipal city waste compost mixture

The 100% urine N-treated plants had the highest significant ($P<0.05$) fresh total plant weight of 23 g plant^{-1} (41.4 t ha^{-1}) at the first planting (Figure 2). The lowest yield of 7.6 g plant^{-1} was recorded from the control plot (no treatment applied) and this yield was not significantly different from other treatments, except that of 100% urine. The results of yield parameters revealed better performance of organic sources on the plants as compared

Table 1. Estimated partial income from *A. caudatus* production for two successive plantings.

Treatments	Fresh total yield g plant^{-1} at planting periods			Yield (t ha^{-1})	[2]Gross income (NGN ha^{-1})
	1st	2nd[1]	Total		
Control	7.6b	5.3	12.9	23.22	928, 800
NPK	11.2b	7.88	19.08	34.34	1,373,600
100% compost	12.1b	5.97	18.07	32.53	1,301,200
100% urine	23a	9.32	32.32	58.17	2,326,800
2/3 urine + 1/3 compost	13.6ab	5.25	18.85	33.93	1,357,200

Means with same letters within column are not significantly different by Duncan's Multiple Range Test ($P = 0.05$).
[1] No significantly difference in mean by Duncan's Multiple Range Test ($P = 0.05$) within the column.
Yield at 40 (farm-gate value) kg^{-1}.
[2] Partial income (without other costs of production).
1 = 150 NGN as on 25 January, 2011.

to mineral fertilizer NPK. The best performance was seen with 100% urine N. A similar trend was observed during the second planting season (residual) for 100% urine N (see Table 1). Estimated partial gross return from the production of amaranth revealed that 100% treatment produced the highest value of 2,326,800 NGN, while the least (928,800 NGN) came from control (Table 1). The effect of the applied treatments on plant stem girth is reported in Table 2. The 100% urine N treatment also resulted in the best stem girth (2.57 cm), followed 100% compost N, while there was no significant difference between the control and NPK treatments.

Table 2. Effect of fertilizer treatments on stem girth (cm) of *A. caudatus*.

Treatments	Stem girth (cm)	
	1st planting	2nd planting
Control	1.85	1.725
NPK	2.02	1.875
100% compost	2.27	1.775
100% urine	2.57	1.950
2/3 urine + 1/3 compost	2.10	1.650
S.E.D. ($P < 0.05$)	0.42	Ns

S.E.D. = Standard errors of differences of means ($P < 0.05$).
Ns = means difference not significant.

Micro-organisms isolated and identified in vegetable samples

Coliforms isolated from edible portions reveal a slight difference in the presence of *Escherichia coli* in samples with 100% urine, 2/3 urine and 1/3 compost and mineral NPK-treated samples from the first planting (Table 3). However, the second (residual) harvest did not show presence of *E. coli*. Also, the number of organisms isolated from the residual planting reduced as compared to the first planting. As shown in the table, the main planting had three basic aerobes isolated from the vegetables. While *Bacillus* spp. and *Staphylococcus* spp. was common to all the samples but samples from 2/3 urine + 1/3 compost, 100% compost and Mineral NPK-treated plots had *Pseudomonas* spp., which was absent in the 100% urine and control treatments. The same aerobes were isolated from main and residual plantiings.

Table 4 shows the total coliform and aerobic microbial species count from the harvested amaranths in the first and second planting. The result reveals that samples from control, 100% urine and 2/3 urine + 1/3 compost had highest coliform counts as compared with NPK and 100% compost treatments in the first planting harvest. The lowest coliform count was recorded in vegetables fertilized with 100% compost. At the second planting harvest, urine treatment samples had the highest coliform count. Generally, the coliform count was much reduced in the second planting as compared with the first. Total aerobic count from the first planting harvest followed the same trend in the coliform count, with control and urine samples with counts of 2.9×10^5 having the highest population of aerobes, followed closely by 2/3 urine + 1/3 compost sample. At the second plant harvest, all samples had the same value of 3.0×10^4 aerobic count.

Effects of the applied treatments on soil nutrient properties

Generally, the soil used is acidic with a pH of 4.8. At the end of the experiment 100% urine and urine plus compost plots had their pH reduced to 4.7. The increase in soil organic matter was also noticed in the treated plots. The 100% urine plots had the highest organic carbon 13.08 g kg^{-1} followed by the other two organically treated plots. Effects of the applied treatments on other soil essential nutrient elements determined were not that different (Table 5).

Perception of farmers on the use of urine as fertilizer for crops

Social characteristics of farmers. In general, the majority of the respondents (farmers) in this area of investigation were Christians (i.e., two-thirds). This shows that more Christians are involved in vegetable

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Table 3. Micro-organisms isolated and identified in harvested amaranths.

	100% urine	Control	2/3 Urine and 1/3 Compost	100% compost	Mineral NPK
First planting					
Coliforms					
	Aeromonas hydrophilia	*A. hydrophilia*	*Escherichia coli*	*A. hydrophilia*	*Klebsiella pneumonia*
	Enterobacter aerogenes	*E. aerogenes*	*E. aerogenes*	*E. aerogenes*	*E. coli*
	E. coli	*Proteus vulgaris*	*P. vulgaris*	*Pseudomonas aeroginosa*	*Pseudomonas cepacia*
	K. pneumonia	*Proteus mirabilis*	*P. mirabilis*	*P. mirabilis*	*P. mirabilis*
	P. aeroginosa	*Pseudomonas putida*	*P. putida*	*P. putida*	
Aerobes					
			Pseudomonas spp.	*Pseudomonas* spp.	*Pseudomonas* spp.
	Bacillus spp.	*Bacillus* spp.	*Bacillus* spp.	*Bacillus* spp.	*Bacillus* spp.
	Staphylococcus spp.	*Staphylococcus* spp.	*Staphylococcus* spp.	*Staphylococcus* spp.	*Staphylococcus* spp.
Second planting					
Coliforms					
	A. hydrophilia			*E. aerogenes*	
	P. mirabilis	*P. vulgaris*	*P. mirabilis*	*P. vulgaris*	*P. mirabilis*
	P. cepacia	*A. hydrophilia*	*P. putida*	*P. cepacia*	*P. cepacia*
Aerobes					
	Bacillus spp.	*Bacillus* spp.	*Bacillus* spp.	*Bacillus* spp.	*Bacillus* spp.
	Pseudomonas spp.	*Pseudomonas* spp.	*Pseudomonas* spp.	*Pseudomonas* spp.	*Pseudomonas* spp.
	Staphylococcus spp.	*Staphylococcus* spp.	*Staphylococcus* spp.	*Staphylococcus* spp.	*Staphylococcus* spp.

production than Muslims in the study areas. Eighty-five percent of the respondents reported they have no problem getting land, as long as they could make the proper request for land from the concerned authority.

Farmers' perception and willingness to use urine as a fertilizer. According to Table 6, most of the respondents (69%) had not heard that urine is also a fertilizing agent that can be used for vegetable crop production. Most of the respondents (47%) perceived urine as an organic material, though they never knew it could be incorporated into vegetable crop cultivation. Thirty-five percent perceived it as a good agricultural innovation. A few (7%) felt that it is taboo and not hygienic (28%) to use urine for vegetable crop production. Among the respondents, 77% stated that they do not have any cultural norms against the use of urine for vegetable crop planting. Also, 43% of the respondents felt that urine is an organic matter that could be a good agricultural innovation, while 8% believed that it could be easily available, while only 5% have the opinion that urine would be cheaper. More than two-thirds of the respondents did not have any opinion on religious beliefs against the use of urine for vegetable crop production. Also, 63% (no response) of the respondents did not specify any hindrance in economic terms to the use of urine.

Consumers' perception and willingness to buy vegetables planted with urine as fertilizer

The perception of consumers on willingness to buy vegetables produced with urine fertilizer is reported in Table 7.

Table 4. Counts of total coliform and aerobic species (cfu ml^{-1}) isolated from harvested amaranths.

	Total coliform spp. (cfu ml^{-1})		Total aerobic spp. (cfu ml^{-1})	
Treatments	**1st planting**	**2nd planting**	**1st planting**	**2nd planting**
Control	2.5×10^5	2.5×10^4	2.9×10^5	3.0×10^4
NPK	7.0×10^4	2.7×10^4	1.7×10^5	3.0×10^4
100% compost	2.1×10^4	2.3×10^4	1.2×10^5	3.0×10^4
100% urine	2.5×10^5	3.0×10^4	2.9×10^5	3.0×10^4
2/3 urine + 1/3 compost	2.1×10^5	2.0×10^4	2.6×10^5	3.0×10^4
Mean	19.5×10^4	2.5×10^4	22.6×10^4	3.0×10^4
Min	7.0×10^4	2.0×10^4	12.0×10^4	3.0×10^4
Max	2.5×10^5	3.0×10^4	29.0×10^4	3.0×10^4
SD	8.5×10^4	3.8×10^3	7.7×10^4	0

Sixty-two percent of the vegetable consumers were indifferent to the use of urine as fertilizer in producing vegetables, while just 8% considered urine use in crop production as forbidden by their religions. A greater proportion (24%) of the consumers would buy vegetables produced with urine fertilizer if urine does not pose any health problem, while 29% would purchase the vegetables if they do not smell urine. Only 9% of the consumers indicated interest in buying the vegetables even if nutritional value is affected by the urine fertilizer considering that urine is readily available as fertilizer for crop production.

Table 5. Chemical properties of soil at the end of second planting of amaranths.

Treatments	pH	OC	N	P	K	Ca	Mg	Na	Ex. acidity	ECEC	Fe	Mn	Cu	Zn
		($g\,kg^{-1}$)		($mg\,kg^{-1}$)	($cmol\,kg^{-1}$)						($mg\,kg^{-1}$)			
Pre-planting soil	4.8	8.64	0.9	14	0.4	5.2	1.0	1.0	0.6	8.2	109	179	22	66
1st planting														
Control	4.9	10.44	1.3	13	0.2	6.5	0.4	0.9	0.4	8.4	104	127	33	104
NPK	4.9	12.96	1.7	16	0.2	6.5	0.4	0.9	0.2	8.1	118	142	36	103
100% compost	4.8	11.16	1.8	13	0.2	6.8	0.3	0.9	0.6	8.7	146	102	36	86
100% urine	4.8	12.48	2.4	14	0.2	7.1	0.4	1.0	0.4	9.0	103	126	37	101
2/3 urine + 1/3 compost	4.9	13.68	2.9	14	0.2	7.1	0.4	1.0	0.4	9.1	104	115	35	97
2nd planting														
Control	4.8	11.64	2.5	15	0.3	7.5	0.7	1.2	0.4	10.1	108	170	32	110
NPK	4.8	11.28	1.6	17	0.3	7.6	0.7	1.2	0.4	10.2	104	147	30	90
100% compost	4.8	12.96	2.0	15	0.3	7.9	0.7	1.2	0.4	10.5	106	143	34	96
100% urine	4.7	13.08	1.8	15	0.3	7.6	0.6	1.2	0.2	9.9	108	168	33	104
2/3 urine + 1/3 compost	4.7	12.36	1.9	15	0.3	7.5	0.6	1.3	0.2	9.8	103	160	34	104
Means	4.8	11.88	1.9	15	0.3	7.0	0.6	1.1	0.4	9.3	110	144	33	96
Min	4.7	8.64	0.9	13	0.2	5.2	0.3	0.9	0.2	8.1	103	102	22	66
Max	4.9	13.68	2.9	17	0.4	7.9	1.0	1.3	0.6	10.5	146	179	37	110
Std	0.1	1.45	0.6	1	0.1	0.8	0.2	0.1	0.1	0.9	13	24	4	12

Std = standard deviation.

Discussion

Amaranthus caudatus is usually consumed fresh, thus the emphasis on fresh weight of the plants. The agronomic experiment revealed that the application of 100% urine N resulted in the highest significant ($P<0.05$) fresh total plant weight of $23\,g\,plant^{-1}$ ($41.4\,t\,ha^{-1}$) at the first planting. This yield is far higher than $20\,t\,ha^{-1}$ on a sandy soil of poor fertility status[15]. A similar yield of $16.78\,t\,ha^{-1}$ on similar soils was also reported[16]. Higher and better yield in 100% urine N-treated plants must have been due to the fact that nutrients in urine are in forms that are readily available to plants. The urea in urine readily degrades to ammonium and nitrate ions, both of which are in forms that plants can absorb[7]. The improvement on amaranth yield by the 100% urine N over that of mineral fertilizer NPK is in agreement with reports of other researchers in some parts northern Europe[17,18].

A combination of yields ($t\,ha^{-1}$) from both planting seasons resulted in 100% urine-treated soil producing $58.17\,t\,ha^{-1}$ total plant mass, while NPK 15:15:15 gave $34.34\,t\,ha^{-1}$ total plant yield. It was observed that the estimated partial gross returns of 2,326,800 NGN attributable to 100% urine fertilizer doubled that from the use of mineral fertilizer NPK. This is an indication that urine fertilizer could be profitable.

The results obtained agree with research findings from Uganda where urine was found to increase yield more than mineral fertilizer NPK[5]. It also fits with results from Finland where cabbages grown with human urine performs better than those from conventional plots[6]. Similar results have been seen from previous experiments carried out in the University of Ibadan on *Celosia argentea*[19].

Generally, urine- and compost-treated soils were better in nutrient status at the end of the second planting. This increase in organic carbon might be associated with the increase in microbial activities usually found in fields where organic fertilizers are used[20]. Organic carbon content of the NPK plots was reduced at the end of the experiment (organic carbon at the end of the first planting was $12.96\,g\,kg^{-1}$ and reduced to $11.28\,g\,kg^{-1}$ at the end of the second planting). Total nitrogen of the soil increased from 1.3 up to $2.0\,g\,kg^{-1}$ on treated plots. The least improvement as found on NPK plots ($1.6\,g\,kg^{-1}$). This indicates that urine and compost fertilizers can improve soil nutrient status.

The same populations of aerobes were isolated from main and residual plantings. Generally, high levels of bacteria were recorded in vegetables which were higher than the recommended level of $<10^3$ cfu/100 g[21]. This situation could have been caused by active organisms present in the soil/plant layer interface rather than urine or compost applied. Several factors may account for the high levels of coliform contamination recorded in most of the analyzed vegetables. The principal possible source of the coliform is the application of uncured poultry droppings as fertilizers by the farmers in the investigated area. Fresh poultry litter samples, sometimes used without sufficient drying for vegetable production in Kumasi, had equally high fecal coliform counts between 3.6×10^4 and 1.1×10^7 cfu/100 g.[22]

Comparatively lower levels of bacteria recorded in compost-grown vegetables were indicative of the

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Table 6. Farmers' perception and willingness to use urine as fertilizer.

Parameters	Frequency	Percentage
Knowledge of urine use in agriculture		
Yes	17	28
No	38	63
Indifferent	5	8
Total	60	100
General believe about urine in agriculture		
Possible source of organic fertilizer	28	47
Cheapness	6	10
Ready availability	6	10
Good innovation	20	33
Total	60	100
Personal opinion against use of urine as fertilizer		
Bad smell	23	38
Irritating to handle	13	22
A taboo	4	7
Not hygienic	17	28
Indifferent	3	5
Total	60	100
Existence of cultural norms against use of urine		
Have	14	23.30
Do not have	46	76.70
Total	60	100
Respondents' personal conviction on urine use in agriculture		
Organic fertilizer	26	43
Good innovation	26	43
Would be cheaper	3	5
Availability	5	8
Total	60	100
Specific religious beliefs against urine usage		
Personal reason	6	10
It is forbidden	3	5
Its purity	8	13
No response	43	72
Total	60	100

Source: Field survey, 2009.

Table 7. Consumers' perception and willingness to buy vegetables planted with urine as a fertilizer.

Parameters	Frequency	Percentage
Personal and religious belief against urine usage		
Personal reason	14	14
Its forbidden	8	8
It is impurity	16	16
Indifferent	63	62
Total	101	100
Conditions for buying vegetables grown with urine		
If substitutes are scarce	26	26
If substitutes are available but the vegetables from urine fertilizer are cheaper	18	18
If substitutes are scarce but vegetables are succulent and leafy	14	14
If substitutes are available but the vegetables are fresh and succulent	20	20
If the vegetables are not smelling of urine	29	29
If the vegetables are smelly and odor could be washed away by boiling	23	23
If urine does not pose any health problem	36	36
If it poses health problem but cheaper	18	18
If the nutritional value is not affected	24	24
If nutritional value is affected but readily available	9	9
If no extra cost is incurred in use of urine	11	11
If extra cost is added but vegetable is fresh and succulent	10	10
Total	101	100

Source: Field survey, 2009.

fact that the compost was highly cured and had less bacterial contamination. It was possible that microbes in the urine samples also contaminated the urine/compost composite mixture used in growing vegetables hence the high levels of microbes recorded. In general, the results of the microbial analysis did not establish any negative pathological contamination due to the use of urine. This result is in line with earlier reports that the use of properly treated urine as a fertilizer does not introduce pathological contamination to agricultural fields[7,21].

The perception analysis revealed that most farmers and consumers do not have serious cultural norms against urine fertilizer. Analysis showed that most farmers would use urine for vegetable production if it gives a better yield than other organic fertilizers, while most consumers would buy vegetable crops grown with urine if it does not pose any health problem. These results are similar to a report that people in Eastern Uganda's Mbale District accepted the use of urine as a fertilizer because of the financial gain attached[23].

Conclusion

The results of the response of *A. caudatus* to urine and municipal waste composts and their mixtures as fertilizer revealed that 100% urine performed better as a fertilizer at both main and residual plantings. Financial returns using urine as a fertilizer also doubled that of the commonly used mineral fertilizer NPK. The use of urine as fertilizer for *A. caudatus* improved some useful soil properties and did not result in pathogenic microbial contamination. Although coliform and aerobic bacterial species were detected in the vegetable, this could not be traced to the application of urine or other treatments used in this study but to the poor soil management practices by the farmers before the investigation. Respondents in this study perceived urine to be a good agricultural innovation which can be used for vegetable crop production and did not have any strong cultural norms that could prevent them from using urine for planting or that would prevent them from buying vegetable crops grown with urine. This is an indication that if urine is harvested and made available, farmers would be willing to use it for crop production as long as consumers are willing to buy. However, the logistics of storage and distribution of urine as fertilizer have to be addressed.

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