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Fertilizer Value and the Acceptability of the Utilization of Human Urine in Peri-urban Agriculture; A case study in the Kumasi Metropolis

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ABSTRACT
Until quite recently, human urine has been tagged a 'waste', especially in Africa, even though the eastern, and western worlds have for centuries reaped the immense blessings associated with this "liquid gold". It is in the light of this that this paper discusses the research work conducted to ascertain the fertilizer value of human urine and its utilization in agriculture in Kumasi, Ghana. The study investigated the maximum storage time of human urine that would result in increased NPK for crop use under green house conditions using maize as the test crop. Some morphological characteristics; number of leaves, leave length, plant height and leave width were measured. Perceptions of farmers and consumers on urine use in agriculture were also examined. In a randomized complete block design, fresh urine (0), 1, 2, 3, 4, 5, and 6 months' old urine and NPK 15:15:15 chemical fertilizers were applied to maize crops in a green house. Prior to planting and application of plant nutrients, soil and human urine NPK contents were analysed using standard methods. Fresh urine produced the highest Nitrogen, Phosphorus and Potassium contents of 884.572mg/L, 68.044mg/L, and 180.763mg/L respectively compared to the six months old urine which yielded 700.450mg/L, 0.578mg/L and 0.096mg/L of Nitrogen, Phosphorus and Potassium contents respectively. The amounts of NPK in urine decreased with storage duration. Percentage decrease of urine NPK over the six months of storage were 20.8%, 31% and 22% respectively. Fertilization of maize crops with urine, produced crops with morphological characteristics comparable to plants fertilized with NPK mineral fertilizer – 15:15:15. Farmers, though unaware of the fertilizer value of human urine, were willing to use it in farming. Consumers however were unwilling to patronize vegetables fertilized with human urine.

Introduction

Reports from several parts of the world have indicated that human urine has been used for varying purposes for several centuries. For instance, the use of human excreta in agriculture for food production in China is an old and well known practice (Dunker et. al., 2007). In Japan, the recycling of urine and faeces was introduced in the 12th century (Schönning, 2001). Esrey and Anderson (2001) indicated that urine has been found to be a good substitute for mineral fertilizers in growing cereals, with no negative impact on the crop or the environment

In Europe, Sweden is the country with the most advanced system of collection and re-use of human urine, where it is practiced by farmers on a large, mechanized scale. This technology of recycling human excreta is to ensure sustainable ecological sanitation and food security. Ecological sanitation-ECOSAN or 'dry box toilets' has been used successfully for many years in a number of countries, e.g. Vietnam, China, Mexico, El Salvador, Guatamala, Ethiopia, Zimbabwe and Sweden (Esrey and Andersson, 2001).

The fertilizing ability of human urine stems from the fact that it is a metabolic waste resulting from the breakdown of excess proteins and other mineral substances, hence it contains quite a substantial amount of organic (Uric acid, Creatinine, Urea etc.) and inorganic substances such as the macro nutrients (NPK) needed by plants for growth and other ionic substances like Sodium (Na^+), Potassium (K^+), Magnesium (Mg^{2+}) and Calcium (Ca^+). Of the Nitrogen, 75% - 90% is excreted as urea and the remainder mainly as ammonium and creatinine (Jonsson et. al., 2004b). The amounts of nutrients found in urine and faeces vary from person to person and from region to region depending on the nutrient content of the food consumed (Vinnerås and Jönsson, 2002).

It is surprising to note, however, that nearly all the urine produced in Africa is allowed to go waste. Until recently, little or no research work on urine use had been carried out in Africa. The few researches conducted in Africa have however shown quite astonishing and incredible results. For instance, a study carried out in Ibadan, South West Nigeria, showed that morphological features of maize (Zea mays) fertilised with urine was comparable to those fertilized with organo-meniral fertilizer (OMF) and NPK 15.15.15 (Sridhar et al., 2005). Morgan (2007) reported on trials performed in Zimbabwe on varieties of vegetables, banana and maize using urine diluted with water at a ratio of three parts water to one part urine (1:3) as a liquid feed. According to the report, the application of 1,750ml of urine per maize plant over the 3.5 months growing period resulted in yield

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of 954 grams of maize seeds, compared with 406 grams for maize seeds when fed with 750ml of urine per plant, and only 63 grams for the maize irrigated with water only.

Several ECOSAN projects are ongoing in almost all the francophone neighbours of Ghana and other West African countries. For instance, the research and demonstration programme of CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à faible coût), was started in Benin, Burkina Faso, Côte d'Ivoire, Guinea, Mali, Senegal and Togo in the year 2003. During the research period from 2003 to 2005, ECOSAN fertilizers (human excreta) were successfully tested on different crops (Dagerskog et al., 2008). The results obtained were not different from the work carried out by Sridhar in Nigeria as elucidated above.

In an attempt to research and advocate for the use of human excreta in food production there is the need to take into cognisance the role of socio-cultural and gender issues in achieving ecological sanitation solutions for food production. Dunker and Matsebe (2008) have shown that human excreta are perceived by South Africans as waste products, unhygienic, unhealthy and detrimental to humans. The report further indicated that, the use of human urine in agriculture is generally not accepted; however, with education its use will be feasible.

Though there are only a few organizations working on ecological sanitation in Ghana, many ecological sanitation projects have been tried. Most are small projects, and findings have not been extensively documented. It is therefore quite difficult to get a good sense of what has been done, and how much has been tried (Thrift, 2007).

The study carried out in Nima, a mostly low-income suburb of Accra, Ghana, revealed that respondents perceived the re-use of urine and faecal matter as positive towards achieving urban household food security, and that they would support the implementation and its sustenance (Tsiagbey et al., 2005). The Valley View University in Accra is so far the only recognized institution where ecosan toilets have been built and human excreta utilized in organic agriculture in the university's farms and gardens.

The above empirical evidences clearly show that Ghana has quite a significant potential to harness her untapped resources (human excreta) which is often unfortunately regarded as waste. Agronomically, the utilization of less expensive alternative fertilizers will encourage more food production and this will help government achieve the millennium development goal (MDG) of halving poverty and reducing hunger by 2015. From the environmentalist perspective, the problem of huge investment in treatment and management of human excreta will be reduced so government will channel those monies into other developmental projects. It is in the light of this that this paper seeks to examine the fertilizer value of human urine and the storage duration that will release maximum NPK to crops under the environmental conditions pertaining in the Kumasi metropolis. This paper also examines the influence of urine on the morphological features of a test crop - *Zea mays* when urine is used as fertilizer compared to the use of mineral fertilizer. In addition, Understanding of farmers and consumers perceptions on the use of human urine in agriculture will be essential for urine utilization and future research work in Ghana.

Methodology

Study Area

This research was carried out in Kumasi the capital of the Ashanti region because of the city's geographical significance in Ghana. Kumasi is the second largest city in Ghana and is the capital of the Ashanti region. It is located in the south-central part of the country (i.e., the Rain Forest region of Ghana). Kumasi is approximately 482.7km north of the Equator, 160.9km north of the Atlantic's Gulf of Guinea and 160.9km west of the Prime Meridian. The city has a population of about one million one hundred and seventy thousand two hundred and seventy (1,170,270) and has an annual population growth rate of 5.47% (http://en.wikipedia.org/wiki/kumasi)

Materials and methods

Urine Collection House: The superstructure to house the urine harvesting system was built using locally available materials, bamboo sticks, wood, cement and sand. It was situated behind the department of Theoretical and Applied Biology (TAB) of Kwame Nkrumah University of Science and Technology-KNUST. Each housing unit measured 1.50 m x 2.00 m with a roof made of bamboo. Two of these systems were built (Plate 1a), one for males (Plate 1b) and the other for females (Plate 1c). In each of these housing units, a chamber was provided for urination and the urine directed through a PVC pipe into an 8 litre container placed behind the urinal. The flow of urine was by gravity.

Plate 1a: Male and female urinal | Plate 1b: Male chamber | Plate 1c: Female chamber

Plate 1. Photograph showing the external view of the urinals for male and female (1a) the inner portion of the male (1b), inner portion of the female (1c) Male and female urinal

The experimental urine was collected in well labeled tightly capped 8 Litre containers. The willingness of both students and workers to patronize the urinal and to promote the intended research due to the sensitization campaign amongst the students and workers, resulted in the collection of about 16 litres of urine in 48 hours period. The collected urine was stored for periods of 1, 2, 3, 4, 5 and 6 months under temperature conditions between 23^oC and 32^oC (due to seasonal changes) in the Green-house. The collected urine for each month was stored in separate containers and analysed for their NPK contents using various standard methods; Nitrogen content in urine was analysed using the Photometer method at a wavelength of 450nm, available phosphorus content was analysed using the UV-Visible Spectrophotometry technique and total Potassium content was determined using Flame Photometry technique. The soil used in the Greenhouse study was collected from the TAB experimental farm and the NPK contents analysed using standard methods. The experiment comprised two treatments and a control. The treatments were human urine and NPK 15:15:15. *Mamaba*, a locally developed maize variety was used as the test crop. Six and a half kilograms (6.5 kg) soil sample was put in each of 18 pots assigned for each of the seven (1st, 2nd, 3rd, 4th, 5th, 6th months and fresh urine) setups for the greenhouse experiment. Two maize seeds of *mamaba (*which has a maturity period of 120 days) were sown in the eighteen pots for each setup and thinned up to one seedling after germination. Application of urine and mineral fertilizer were done 14 days after germination of maize. The experimental protocol of Morgan (2003) was adopted using urine diluted at a ratio of 1:3 (urine: water). The seedlings were each regularly fed with 250 ml of tap water.

Table 2.0 Available NPK for Plant use over different storage durations and comparison of all possible pairs of mean NPK concentrations in human urine using Duncan's Multiple Range Test (DMRT)

Storage Duration (months)	Nitrogen		Phosphorus		Potassium	
	Concentration/ (mg/L)	DMRT[y]	Concentration/ (mg/L)	DMRT[y]	Concentration/ (mg/L)	DMRT[y]
Fresh	884.572	a	68.044	a	180.763	a
One	874.310	a	58.640	c	180.330	a
Two	807.243	c	67.040	a	164.433	a
Three	654.330	f	50.241	d	132.423	b
Four	832.572	b	64.044	b	176.532	a
Five	676.572	e	52.044	d	142.520	b
Six	700.450	d	46.950	e	140.85	b

[y]*Any two means having a common letter are not significantly different at 5% level of significance*

Table 3.0 Comparative effect of urine and mineral fertilizer on leaf formation and plant height of maize seedlings after 8 weeks of planting at 28 ^{0}C in the greenhouse

Duration (Months)	Treatments	No. Of leaves (mean)	Plant Height/cm (Mean)	Leaf length/cm (mean)	Leaf width/cm. (mean)
Zero	Urine	15	131.5	82.7	5.5
	NPK 15.15.15	16	152	81.8	5.9
	Control	14	127	79	5.0
One	Urine	15	153.0	94.8	6.2
	NPK 15.15.15	16	153.8	92.7	6.5
	Control	13	134.5	80.3	5.1
Two	Urine	15	153.0	94.8	6.2
	NPK 15.15.15	16	153.8	92.7	6.5
	Control	13	134.5	80.3	5.1
Three	Urine	16	166.5	87.5	6.3
	NPK 15.15.15	16	166.0	92.3	6.3
	Control	14	135.0	69.3	5.1
Four	Urine	16	146.7	71.2	5.6
	NPK 15.15.15	16	146.3	78.2	6.2
	Control	14	140.7	73.2	5.0
Five	Urine	14	139.0	86.5	6.1
	NPK 15.15.15	15	157.5	94.7	6.9
	Control	14	114.5	79.5	5.1
Six	Urine	15	153.2	94.8	5.8
	NPK 15.15.15	15	156.0	98.0	6.7
	Control	13	132.8	80.3	4.9

The treatment included application of diluted urine at a rate of three times a week for two weeks; mineral fertilizer (NPK; 15:15:15) application at a rate of 2.7g per pot in accordance with the protocol described by Sridhar *et al.,* (2005). Each setup was replicated three times and arranged in a randomized complete block design (RCBD). This design was repeated to increase the replicates to six. There were a total of six applications of urine to each plant. Mineral fertilizer was however applied once (i.e., second week after planting). Some important morphological features such as number of leaves, plant height, leaf length, leaf width were measured every fortnight until the eighth week of planting.

In the bid to ascertain the acceptability or otherwise of urine use in agriculture, a structured questionnaire was designed and administered to 40 randomly selected farmers in three farming sites and 40 consumers in three different suburbs (Bomso, Oforikrom, Ayigya Zongo) in the Kumasi metropolis.

Analysis of Data

Both qualitative and quantitative component of the data were analysed using the SPSS statistical software. The quantitative component of the data was subjected to analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT) at the 0.05 level of significance was run to ascertain the level of significance of the mean NPK concentrations in human urine.

Results and Discussion

Generally, the results of the study reveals a decrease in availability of elemental nitrogen, phosphorus and potassium (NPK) for plant use with storage duration and this decrease is statistically significant (table 2.0). The decrease in nitrogen content in urine could be attributed to the formation of a gas (NH_3) which escaped by virtue of the frequent opening of the storage containers to pick samples for analysis and application to crops. There could not have been any means by which elemental nitrogen in urine would decrease with storage duration if not forming sediments and settling or forming a gas and escaping through gaseous means. Jonsson *et al.,* (2004) reports that, 75%-90% of Nitrogen is excreted as urea and the remainder mainly as ammonium and creatinine. In the presence of urease, urine is quickly degraded to ammonium and carbon dioxide and the hydroxide ions produced normally increases the pH. The high pH of the urine in the storage vessels, coupled with its high ammonium concentration results in the formation of ammonia gas.

According to Udert *et al.* (2003), about 30% or more of urine Phosphorus turns into sludge at high pH (which eventually settles as a bottom layer). Since phosphate turns insoluble (sludge) with increase in pH, that could account for the decrease in the Phosphorus levels with storage duration. Other such physical and chemical factors could have also accounted for the decrease in potassium content in urine.

Again, the morphological features of the maize plants treated with urine and mineral fertilizer for all the seven setups generally exhibited comparable characteristics as shown in table 3.0. For instance, treatment of maize plants with six months old urine produced plants whose leaf lengths, leaf widths and plant heights were comparable to those treated with mineral fertilizer-NPK. Observations during the growth period for all the seven setups showed that urine fertilized crops appeared greener and nicer as compared with NPK 15.15.15 fertilised crops. It must be stated that the first week of urine application resulted in the retardation of plants' growth rate. The change in soil pH due to addition of urine reduced the absorption rate of the plants, hence the sluggish growth few days after urine application. These plants however picked up afterwards and developed morphological features comparable to those fertilized with NPK 15.15.15. Dagerskog *et al.* (2008) have shown that ECOSAN-fertilized crops look very nice and their harvest periods however are significantly extended. Again, it was observed that urine fertilized soil could retain much moisture than mineral fertilizer fertilized soils and the control.

Acceptability of the use of human urine in agriculture

Majority of the consumers and farmers in the metropolis attach some cultural values to human urine in one way or the other. They perceive urine to be good for healing of diseases, determination of whether one is sick or not. Also one becomes spiritually unclean as a result of touching and or being touched by human urine. Both farmers and consumers in the metropolis perceive urine to be 'unhygienic', 'filthy', 'smelly' and 'toxic to plant health'. Seventy percent (70%) of the farmers perceive, human urine to be harmful to plants as it burns and kills plants. The farmers were willing to use urine for farming and would consume food grown with human urine. On the contrary, the consumers would not entertain food produced from urine fertilization and would therefore not advocate the use of urine for farming. Both farmers and consumers however, agreed on the position that urine should not be used in the cultivation of vegetables. Urine should rather be used in growing grains, tubers and ornamental crops. Interestingly, farmers in the metropolis were willing to offer their urine for farming purposes. In contrast, the consumers were unwilling to donate their urine for any farming venture.

Conclusion

The duration of storage of human urine has a significant effect on its fertilizer (NPK) value. Over the storage period, more of the nitrogen content of urine is converted to ammonia gas which is eventually lost to the atmosphere. Fresh and one month old human urine releases the maximum NPK for plant use. Urine fertilized plants were found to be morphologically comparable to plants fertilized with NPK 15.15.15. Farmers and consumers in Kumasi are unaware of the fertilizer value of human urine. It is evident from the foregoing discourse that education and provision of demonstration farms among others is needed to change people's orientation towards the use of this all important and indispensable resource in agriculture and enhancing good sanitation in Kumasi and Ghana in general.

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