URINE FERTILIZER FOR VEGETABLE PRODUCTION - A CASE STUDY IN NEPAL AND GHANA

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ABSTRACT

Eco-toilets (human urine and faecal matter collected separately) are one of the best ways to solve sanitation problem, and this practice also improves the environment and increases the food production. This study focuses on experimental demonstration of use of urine, wood ash and poultry droppings (PD) as a fertilizer in central Nepal and in Accra, Ghana. In Nepal; Fertilizer value of urine+ash was compared with animal manure and no-fertilization in the cultivation of radish, potato, broadleaf mustard, cauliflower and cabbage. The urine + ash or manure fertilized plots received 54 kgN/ha for radish, 51 kgN/ha for potato, 81 kgN/ha for broadleaf mustard and 77 kgN/ha for cabbage and cauliflower. Similarly in Ghana; urine was compared no fertilization and urine + PD (poultry dropping) was compared with NPK (mineral fertilizer)+PD as a dose of 121 kgN/ha.

In Nepal; the urine+ash fertilizer produced significantly ($P<0.05$) higher broadleaf mustard biomass than obtained from animal manure and without fertilization. It was demonstrated that urine+ash can produce higher yields than manure fertilizer; the differences being >24 t/ha radish tuber, >95 kg/ha potato tuber, >19 t/ha cauliflower total biomass and >15 t/ha cabbage total biomass. In Ghana; urine produced 1.2 ton/ha more cabbage head biomass compared to no fertilization and urine+PD produced 0.82 t/ha more cabbage head biomass compared to NPK+PD. Furthermore, in Nepal; N-fertilizer value of 4 litres urine is equal to the 1 kg of dry manure and in Ghana N-fertilizer value of 2 litres of urine is equal to 1 kg of poultry droppings. In conclusion, ***human urine can be used as fertilizer alone or combined with wood ash and poultry droppings and this can produce similar or even more vegetable biomass than can be achieved with no fertilization, manure fertilization or NPK+PD.***

Keywords: ECO-SANITATION, FERTILIZER, GHANA, NEPAL, URINE, VEGETABLES, WOOD ASH

INTRODUCTION

Around 2.4 billion people do not have sanitation facility and about 2 million people die every year due to diarrheal diseases, most of them are children <5 years of age (WHO 2010). On the other hand, fertilizer demand is increasing by increasing food demand to feed the increasing population. Since fertilizer is a very important means to increase the food and fertilizer is becoming expensive, (Hargrove, 2008) this problem can be partly solved by using human urine fertilizer. The use of urine as a source of fertilizer has been tested and accepted in Finland, South Africa, Israel and China (Pradhan et al. 2007, 2009; Jönsson, 2004). In addition, wood ash is also an abundant waste in many areas and this has been used as fertilizer, too (Erich 1991).

Nepal is a developing country located in South Asia with 29 million inhabitants (UNFPA 2007). The sanitation coverage among the relatively wealthy is 80% whereas it is only 12% among the poor (IYS 2008).

On the other hand, in 2006 according to FAO, 16% of the population was under nourished (FAO 2010). Since eco-sanitation and use of human urine as a fertilizer are a novel concept in different parts of Nepal country, it is very important that many of the population receive knowledge about these topics and it is also equally important to evaluate their true opinions and their current awareness or knowledge.

Currently farmers in Accra, practicing vegetable production by using mineral fertilizer and poultry manure. The high cost of mineral fertilizers is a constraint to farming activities in the city. On the other hand, 95% of the city's populace uses on site sanitation facilities (Cofie *et al.,* 2007). Public toilets are common, and there are public urinals which are located within some of the densely populated areas. But collected urine has been disposing in gutter therefore this study investigates the possibilities of use of urine fertilizer in vegetable production. Human urine contains essential nutrient needed in agriculture. The fertilizer value of pure urine is similar to NPK 18:2:5 (Ganrot, 2005).

The main objectives of the study were 1) to demonstrate the practical implementation of use of urine+wood ash in a cultivation experiment in Nepal and 2) to determine the fertilizer value of urine and urine+PD in vegetable cultivation in Ghana. However, this paper mainly present the study conducted in Nepal but also present the main results from experiment in Ghana.

DATA AND METHODS

Experiment In Nepal Study Area

This study was conducted in Chanauta (814m above sea level, 83.98^{o}E and 27.72^{o}N), Minaghat-1 Nawalparasi district in central Nepal, from November 2009 to February 2010. Total population in this study area is 247 (124 males and 123 females) (Population census 2006). The study area is located at the top of a hill and it is not connected by any roads. The nearest off-road is about 3-4 hours walking/tracking distance. In this study area, Magar was the dominated ethnic group and agriculture was their main activity. The main crops, all mainly for home consumption, were rice, pearl millet, finger millet, maize, ginger, mustard, potato, broadleaf mustard, radish etc. All the villagers used firewood for cooking.

Urine, Wood Ash and Manure

The local people were asked to collect and bring urine from their house and pour it into the 200 L urine collecting tank kept in the school, the urinal was also used by students and teachers. Similarly, the villagers were also asked to bring animal manure (mainly cow and goat manure) and wood ash from their home. This manure and wood ash was sieved and mixed carefully before use for cultivation. The physico-chemical parameters of field soil, manure, urine and wood ash are given in Table 1.

Table 1. Physico-chemical parameters of experimental soil and the fertilizer materials. (NPK unit for urine is g/L)(ND = Not determined)

Materials	N (g/kg)	P (g/kg)	K (g/kg)	pH	conductivity µS/cm	Mg (g/kg)	Ca (g/kg)	OM %	Carbon %
Soil (DW)	4	0.02	0.2	4.7	82			1.8	
Manure (DW)	11	0.4	7.7	8.7	1787			17.9	
Urine	2.9	3.1	9.5	9	21803			ND	
Wood ash	0.9	0.2	ND	11.8	1310	2.8	22.8	ND	
Chemical characteristics of soil and other fertilizer sources in Accra experiment									
Soil	0.5	0.5	0.2	7.0	275				13.60
Urine	10.3	1.0	07.5	8.5	>3000				ND
PD	19.6	19.5	12.3	6.8	1650				15.41

Cultivation Experiment

In the cultivation experiment, three volunteers were trained to use animal manure, urine and ash fertilizer in the cultivation experiment (Figure 2B). Radish (*Raphanus sativus* L), potato (*Solanum tuberosum* L.), broadleaf mustard (*Brassica juncea* L.), cabbage (*Brassica oleracea* L. F1) and cauliflower (*Brassica oleracea*

L.) were cultivated by using animal manure fertilizer and human urine + wood ash as fertilizer (Table 2). The non-fertilized plots were utilized as a control treatment.

Table 2. Design, segments and amount of different fertilizer and nutrients applied in different vegetables. (Here, -3 days indicates that the fertilizer was applied 3 days prior to the planting)

Subjects	Radish	Potato	Broadleaf mustard	Cauliflower	Cabbage
Plot area (m^2)	1.1 (0.4×2.75m)	1.15 (0.5×2.3m)	0.75 (0.5×1.5m)	0.75 (0.5×1.5m)	1.05 (0.6×1.75m)
Plants/plot	10	6	4	5	5
Applied amount of urine (L/m^2)	1.8	1.7	2.7	2.7	2.6
Interval for urine application (days)	12, 22, 33	10, 25, 44	-3, 25	-3, 25, 45	-3, 25, 45
Applied amount of wood ash (g/m^2)	230	174	333	333	248
Applied amount of manure (g/m^2 DW)	455	433	667	667	676
Harvested time since the cultivation (days)	62	105	59	87	88
Nutrients applied					
Urine+ash (N-P-K g/m^2)	5.2-5.6-17.1	4.9-5.3-16.2	7.8-8.4-25.7	7.8-8.4-25.7	7.5-8.1-24.7
Manure (N-P-K g/m^2)	5-0.2-3.5	4.8-0.2-3.4	7.3-0.3-5.1	7.3-0.3-5.1	7.4-0.3-5.2

The cultivation was arranged as four replicates for each treatment with a total of 12 plots for each experimental plant species. The cultivation experiment of the same plant species were arranged in six rows (60 cm space between the rows) and two columns (1 m space between the columns in order to avoid leaching of nutrients from one plot to the other plots). This experiment was mainly planned according to with different nitrogen forms and amounts but the other applied main nutrients were also calculated (Table 2). In this experiment, urine fertilizer was applied in different interval days of cultivation (Table 2) but animal manure and wood ash were applied only once three days after planting for all the experimental plant species. However, all the fertilizations were applied some 10-20 cm around the plants and after all applications of these fertilizers; the soil was tilled and mixed carefully.

Figure 1. Cultivation experiment (A) growing seedlings; (B) preparation of field, adding animal manure and wood ash; (C) irrigation of cultivated vegetables; (D) harvesting and measuring the vegetables.

Experiment in Ghana

In Accra, there were four treatments, i.e. (1) urine alone (U), (2) U + PD, (3) NPK + PD and (4) a control. The rate of fertilizer application for each treatment was 121 kg N/ha (Adamtey, 2006). The urine was collected and stored for 1 month before application and PD was brought from nearest poultry farm. Different physicochemical parameters of used urine, PD and field soil are given in Table 1. Urine was applied 20 cm around the plants and covered immediately with soil as described by Heinonen-Tanski and Wijk-Sijbesma (2005). This simple practice mimics the successful injection technique used by Richert Stintzing et al. (2002) to avoid ammonia losses. The soil was slightly watered late in the evening before the urine application to avoid volatilisation.

Experimental Design

Cabbage (*Brassica oleraria*) was cultivated in a Randomised Complete Block Design (RCBD) was used (Figure 2). Each experimental plot was replicated three times. The total plot size was 11.4 m x 20.4 m and each experimental unit was 3.8 m x 3.4 m consisting of four rows of 28 plants (Figure 4a) and the planting distance was 60 cm x 45 cm (Figure 2).

Figure 2

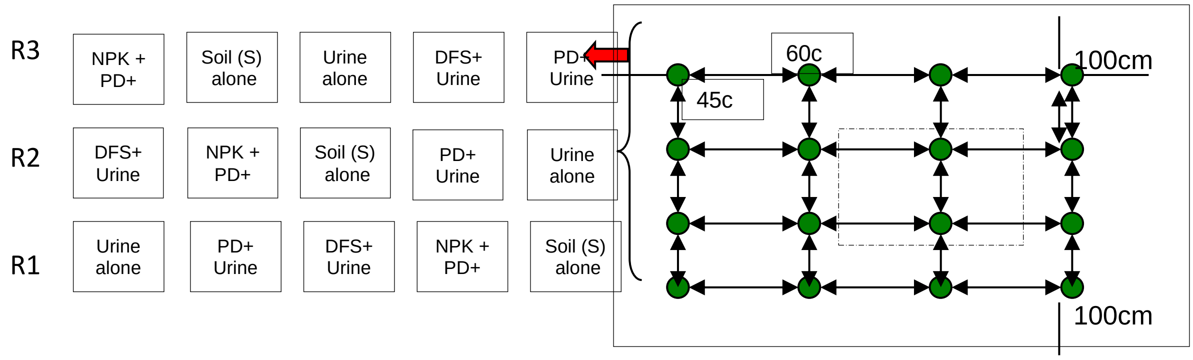

Figure 3. Applying urine fertilizer around small cabbage plant.

Data Analysis

The primary data were collected into a Microsoft Excel file and the basic analysis performed. These Excel data were transformed into SPSS 14.0 for Windows and tested for normality before the appropriate statistical analysis.

RESULTS AND DISCUSSION

Quality of Urine, Wood Ash, Animal Manure and Cultivation Soil

The N content in the collected urine in Nepal was lower compared to the result of Regmi (2005), Mnkeni et al. (2008) and Pradhan et al. (2009). The lower N in NPK ratio might be due to low protein intake of the villagers as a vegetarian diet. The daily protein intake in Nepal was only 61 g/person/day while in Finland and the United Kingdom it was 105 g/person/day in 2003-2005 (FAO 2009). In this village it might have been even lower but not measured. It is well known that protein intake determines the urinary urea excretion (Maroni et al. 1985) and/or protein-N intake and urinary-N excretion are correlated (r = 0.76) (Ziegler et al. 1977). On the other hand, P and K^+ contents in the collected urine were higher compared to these elements present in urine collected in another part of Nepal (Regmi 2005). The high P and K^+ content in urine might have been caused by the fact that their diet was mainly vegetarian and it is known that the vegetarians excrete more K^+ (Ophir et al. 1983). On the other hand, N content in urine collected in Accra was higher than it was in Nepal (Table 1) this might be due to consumption of protein containing food and water evaporation from urine in high temperature in Accra.

Although there is a recommendation to store urine for more than six months at 20^{o}C for hygienic reasons (Höglund et al. 2002), in this study the collected urine was stored for >2 weeks (mean temperature 28^{o}C) before use as fertilizer since there was no possibility to store urine, and urine was needed for fertilization. Anyhow, there were no faecal coliforms detected in 100 ml of collected urine in agreement with previous studies (Pradhan et al. 2007, 2009; Chandran et al. 2009).

The nutrients present in animal manure (Table 1) were comparatively lower than the values reported by Lupwayi et al. (2000) in cattle manure from Ethiopia (i.e. N = 24.8, P=6.1 and K^+ = 32.2 g/kg DW). This might be due to unmanaged storage of manure and the manure was collected by sweep animal dung from the shed and piled-up in an uncovered soil pit from where N may be leached away during the monsoon and/or it may evaporate in the tropical sun. Furthermore, although N content in PD was high additional urine nitrogen have been better for vegetable production this might be due the nutrients in PD is not easily plant available so addition of urine nitrogen gave better result.

Biomass Production

The cultivation segment of this study in Nepal tried to highlight the fertilizer value of human urine and wood ash as shown previously (Pradhan et al. 2007, 2009; Mnkeni et al. 2008; Erich 1991).The total and root biomasses of radish, total and tuber biomass of potato, total and flower biomass of cauliflower and total and head biomass of cabbage produced with animal manure and urine + ash fertilizer did not differ statistically significantly ($P > 0.05$, N=4). On the other hand, the biomass of some other of the urine+ash fertilized vegetables was found to be significantly higher than manure fertilized vegetables. Similar results were reported by comparing urine with mineral fertilizer for cabbage (Pradhan et al. 2007) and tomato (Mnkeni et al. 2008). The biomass of broadleaf mustard was significantly higher compared to manure and non-fertilized plants (Table 4). Partly the statistical non-significance in results was caused by high standard deviations, which can be caused by the heterogeneity of the soil and also there was no pest control. Furthermore, in Accra, urine alone and urine+PD produced slightly higher amount of cabbage head biomass compared to it was produced by none fertilized and NPK+PD, respectively. This result also agree that nutrients content in urine is easily available as liquid form but nutrients content in PD might be release slower.

Table 4. Yields biomass (fresh weight) of different vegetables produced with different fertilizations (calculated as tons/ha) mean ± standard deviation) (N=4).

	Different fertilization treatments			
Vegetables	None	manure	urine+ash	
Radish (Total biomass)	31.30±15.21	31.14±4.97	59.15±30.0	
Radish (Root biomass)	22.66±10.98	22.5±3.35	46.26±16.68	
Potato (Total biomass)	1.7±0.3	1.6±0.1	1.6±0.3	

Potato (Tuber biomass)	1.6±0.3	1.4±0.2	1.5±0.3	
Broadleaf mustard (Leaf biomass)	7.2±1.5	9.3±4.3	19.7±3.7	
Cauliflower (Total biomass)	20.3±14.0	16.8±11.2	16.8±20.1	
Cauliflower (Flower biomass)	8.1±8.9	24.0±9.7	42.7±27.1	
Cabbage (Total biomass)	25.6±8.8	24.1±4.6	39.6±12.4	
Cabbage (Head biomass)	18.5±6.1	19.3±7.6	30.5±12.7	
Results from cultivation experiment in Accra				
	Control	Urine	Urine+PD	NPK+PD
Cabbage head (fresh weight	18.66	19.79	23.4	22.58

In Nepal the amount of nitrogen fertilizer used was still very low compared to fertilization recommendations (Pradhan et al. 2007; Mnkeni et al. 2008). The too low amount of urine used in fertilization was caused by the fact that there were only low volumes of urine possible because the villagers and students still practiced open urination.

After harvesting when the cultivated vegetables were distributed to the Nepali villagers, none of the villagers were suspicious and tried to avoid the vegetables produced with urine + ash possible partly due to the fact the vegetables cultivated using urine+ash tended to be the largest ones. All the vegetables including urine + ash fertilized vegetables were accepted and happily consumed in family meals. This result stress that it might be easier to make human urine an acceptable fertilizer by repeating this type of cultivation experiment in different places.

CONCLUSIONS

This study showed that direct involvement of the villagers in this study was a very effective way to allow them to grasp the concept of eco-sanitation. In the experimental study, urine + ash fertilizer produced 104% and 106% more radish root biomass, 89% and 90% more radish total biomass and 174% and 112% more broadleaf mustard biomass compared to what can be produced without fertilization and with manure fertilizer, respectively. Similarly, urine + ash could produce 111% and 78% more cauliflower total biomass, 55% and 64% more cabbage total biomass and, 65% and 58% more cabbage head biomass compared to the situation without fertilization and with animal manure fertilizer, respectively. In fact, the farmers were made aware of the valuable information that the fertilizer value of 4 litres of human urine was equal to 1 kg of dry animal manure on the basis of its N content. In Ghana; urine fertilizer produced 1.1 ton/ha more cabbage biomass compared to without fertilization and urine +PD produced 0.8 ton/ha more cabbage compared to NPK+PD. Therefore, human urine can be used as fertilizer alone or combined with wood ash and poultry droppings and this can produce similar or even more vegetable biomass than can be achieved with manure fertilization or mineral fertilization+PD.

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