overall project:

Experiences from the use of urine in Arba Minch, Ethiopia

Urine crop trials in Arba Minch, Ethiopia, showed the possibility for improving soil fertility and increasing crop yield.

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Abstract

In this paper an overview of practical experiences with the collection and the use of urine from urine diversion dry toilets in Arba Minch is discussed. At two crop trial sites maize was fertilized with urine and the maize yield and the effect on soil was studied. At one site, the yield of urine fertilized maize was increased seven times compared to unfertilized soil. Analyses of the soil fertilized with urine showed that Kjeldahl nitrogen and salinity was increased while pH was decreased at higher rates of urine application. Urine contains important nutrients for the plants and increases the quality of soil; however precautions against the development of salinity in the roots of plants are required. The urine crop trial sites have changed the attitude of many people who had a chance to visit.

Introduction

The EU-funded project called ROSA (*Resource-Oriented Sanitation concepts for peri-urban areas in Africa*) proposed resource-oriented sanitation concepts as a route to sustainable sanitation to meet the UN MDGs. These concepts have been applied in four pilot cities in Eastern Africa, namely Arba Minch (Ethiopia), Nakuru (Kenya), Arusha (Tanzania) and Kitgum (Uganda). Arba Minch is located about 550 km south of Addis Ababa, the capital of Etiopia, and has a population of about 80'000. ROSA Arba Minch was working in the whole of Arba Minch town on the management of solid waste, greywater, faeces and urine to improve sanitation of the town and to increase agricultural productivity in the Arba Minch area. Different resource oriented sanitation systems have been implemented in Arba Minch town including 15 urine-diversion dry toilets (UDDTs), 30 Fossa alternas, 9 Arborloos, 7 greywater towers, 1 biogas unit and more than 5 composting sites.

One of the most commonly used technologies for the source separated collection of urine are UDDTs. Urine is diverted from faeces using separating pedestals. Urine is a valuable flow since it contains phosphate, nitrogen and potassium and can be used directly or after storage. It is a low cost alternative to the application of nitrogen rich mineral fertilizer in plant production. The chemical composition of urine and its plant availability is comparable to chemical fertilizer (Johansson et al. 2001; Kirchmann and Pettersson, 1995).

Figure 1: Typical storage tank in UDDT toilet

Figure 2: Urine storage in UDDT toilet

Considering the contents of the major nutrients in urine, research in applying urine in agriculture especially in developing countries is needed. The use of urine as fertilizer in arid and semi arid regions like Arba Minch gives some knowledge input and also may contribute to the change of the attitude of the people and even decision makers.

The use of urine in agriculture may increase agricultural production and eventually reduce vulnerability in developing countries.

The objective of the research conducted in Arba Minch town was to test urine as fertilizer for maize on two types of soil with different fertility. The yield of maize was used to evaluate the effect of urine application. The impact of urine on the quality of the soil was also investigated by measuring parameters such as conductivity, pH and nutrient content. The trial sites were furthermore used to demonstrate the use of urine to farmers and other community members.

Use of urine and analyses

Urine separation, collection and transport in Arba Minch

Urine is stored in plastic jerry cans or plastic water tanks, which are available from local market, in the vaults of the UDDTs. Joints of urine collecting pipes are connected by adhesives and flexible plastic pipes are used to reduce nitrogen losses in the form of ammonia. The sizes of the tanks depend on the size of the family using the UDDT. Initially, the transfer of urine from the UDDTs tank into the transportable jerry cans was done by pump. However, this resulted into breakage of two pumps, therefore, a cheap method of collection was introduced which is a plastic hose connected at the bottom of the urine tank and lowered to pour the urine and raised and bent to seal it (Figures 1-2). In some occasions neighbours were complaining and UDDT owners were also ashamed of the odour produced when the stored urine was transferred into transporting jerry cans. Taking this as lesson urine was poured carefully from container to container to avoid nuisance.

Initially, the urine used to be transported by the ROSA project in a pick-up car (Figure 3). However, this was not sustainable. Therefore, female and youth group has been identified which has been originally organized to collect the town solid waste from households and business centres. These entrepreneurs are now transporting urine from UDDT toilets to the area of use by donkey carts (Figure 4). The donkey cart was given by ROSA under the condition that the entrepreneurs transport excreta and solid waste to earn extra income by transporting things different from waste. The UDDT users have proposed a certain amount of money they are willing to pay for these services.

For a hygienic point of view, human urine is a "safe" fertilizer with less concern regarding risks for disease transmission when handling (Kvarnstrom, *et. al*., 2006) and it is an uncommon transmission route of disease. In rural Ethiopia, it is common to urinate on fresh wounds to stop bleeding. In order to reduce the risk from possible contamination by faeces, urine is stored at the production or reuse sites. Some families were using the fresh urine directly in their gardens. Urine is one of the components of co-compost produced by organized youth groups; recently the compost producers have started selling their products to private farmers.

The use of urine as a fertilizer in agriculture in Ethiopia is generally faced with some cultural objections, although wastewater use in agriculture is a common practice in Addis Ababa. In Arba Minch reuse of urine was not practiced until ROSA started it in trials. There was a widespread perception that urine may burn the plants. A part from the burning effect, many households in Arba Minch, who were interviewed in the beginning of the project, stated that they would be hesitant to eat vegetables fertilized by urine. Nevertheless, urine trial farms were prepared in Arba Minch. The trial sites were successful in showing that urine

Figure 3: Transportation by pickup car

Figure 4: Donkey cart used for transporting urine, solid waste, and dried faeces

Table 1: Urine application on the maize plant at Arba Minch University Plot (planting on 28.06.2007)

Code	N applied (kg N/ha)	Urine added (ml)				
		21.6.07	04.8.07	28.8.07	17.9.07	Sum
T25	25	100	50	50	38.1	238.1
T50	50	200	100	100	76.2	476.2
T75	75	300	150	150	114.3	714.3
T100	100	400	200	200	152.4	952.4

improves yield and they were also successful in initiating an attitude change. Many people in Arba Minch have eventually consumed urine fertilized maize, lettuce and tomato although they knew it was fertilized by urine.

Methods

Urine fertilizer trials

Arba Minch University farm trial plot

The urine, which was collected from UDDTs, was transported in 20 litre jerry cans and stored in a tank located at the farmland. Twenty plots each with a size of 16 m^2 were prepared in Arba Minch University farm (Figures 5). Five application rates of urine based on nitrogen amount were chosen including four replicates. The application rates were 25kg N/ha, 50kg N/ha, 75 kg N/ha, and 100kg N/ha, respectively (Table 1). The yield of each plot was analyzed when the crops were mature.

Figure 5: Urine application method on farm

The application of urine was done by watering cans after mixing with 50% irrigation water. The plants were counted in rows; the urine irrigation water mixture was applied nearby the roots of the plants keeping the watering at the same pace. The application was done back and forth until the mixture in the watering can was finished (Figure 5).

The application of the urine on the farm was done in different portions at different development stages of the plant before the first signs of the maize tassel and cob appearance. Operators applying urine in the farm were complaining of strong smell in the direction of wind but there have been no problems with odour once the urine was poured on the soil even at high temperatures in Arba Minch.

ROSA office farm trial plot, Secha

Two plots each with a size of 4 m^2 and 16 planting spots were prepared at the ROSA office site and two maize grains were planted in each spot. Each spot of the first plot was treated with 1.2 litres of urine in four portions while the second plot was watered only with water. All watering was done at the same day for all plots. The amount of nitrogen added in terms of urine was 175 kg/ha. Finally, each plant stand was analyzed for the yield and biomass when the crops were mature.

Physicochemical analysis

2.5 gram of soil taken from 20 cm depth were analyzed for potassium using flame photometer after extracting with 100 ml of ammonium acetate buffer solution (Dewis, *et al*., 1970, APHA, 1992). 2.5 gram were analysed for Kjeldahl nitrogen (TKN) after extraction (Dewis, *et al*.,1970, APHA, 1992). pH and conductivity were analysed after shaking the dispersed sample (1:5 sample: water) (Dewis, *et al*.,1970). Urine was analysed for phosphate, potassium, nitrogen, pH and conductivity according to standard methods (APHA, 1992).

Results from crop trial plots

Characteristics of urine

The urine samples were collected from ROSA office for use at the ROSA office trial plot and from construction site UDDT toilets for use at the Arba Minch University trial plot as described above. Table 2 shows the charcteristics of the urine from the 2 sites.

Table 2: Typical characteristics of nutrients in urine collected from two UDDT sites in Arba Minch (ROSA office and construction site)

Sample/Parameter	NH_4^+-N	N-org	TKN	PO_4^{3-}-P	K^+	pH	Conductivity
	g/l	g/l	g/l	g/l	g/l	-	mS/cm
Urine ROSA office	3.3	0.3	3.7	0.4	1.6	8.8	25.9
Urine construction site	3.9	0.4	4.2	0.6	2.7	8.9	35.8

It was shown that there is a difference in quality depending on way of storage, storage time and the differences in use of the toilets. The urine from ROSA office was collected from office workers who drink water when they need and the urine from the construction site UDDT was collected from day workers who had a possibility of dehydration. Besides, the conductivity of urine from the construction site was higher maybe because it was stored for a number of days in open sun in a water tank but the urine ROSA office was relatively fresh and was stored under the shade in the vault of UDDT.

Crop yields from trial sites

Figures 6-8 show the maize yield on Arba Minch university trial farm which was fertilized by urine at the rate of 25, 50, 75 and 100 kg N/ha, respectively. Figure 7 shows the maize yield increases with increasing urine application rates. However, finally the increase is stabilized with the increase of urine amount. The difference between the yield of the fertilized and unfertilized maize was not much compared to the results from the ROSA office trial plot shown in Figure 9-12. Figure 8 shows biomass of maize without the cob but the change is not significant. One reason for this might be the damage caused by wildlife before analysis. Figure 9-12 show the results of the ROSA office

Figure 6: Urine experiment on maize at Arba Minch University farm

Figure 9: Left: urine fertilized; right: unfertilized maize collected from ROSA office farm.

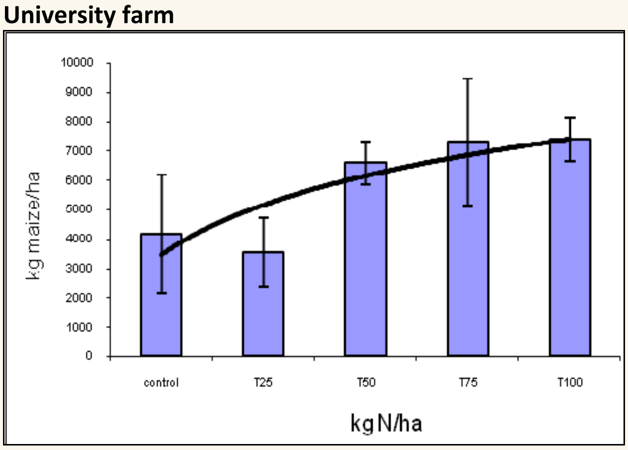

Figure 7: Maize yield (crop trial performed on Arba Minch University farm. The farm land is relatively fertile)

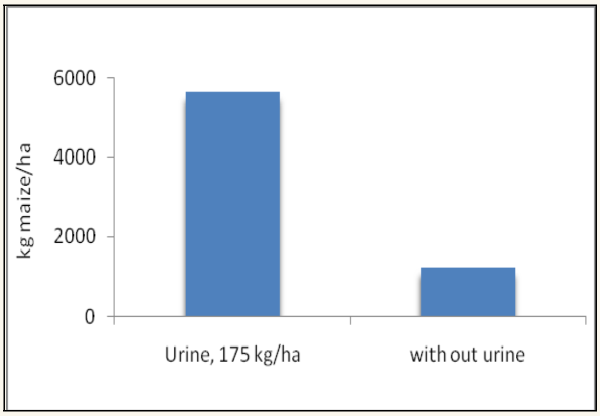

Figure 10: Maize yield (crop trial results of the ROSA Office demonstration farm)

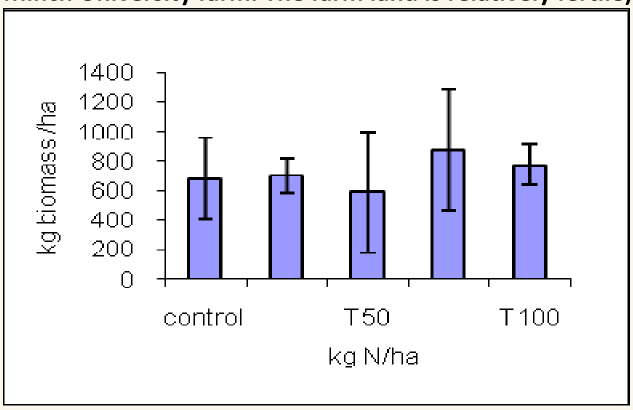

Figure 8: Average of maize biomass measured without cob cover and root (University farm)

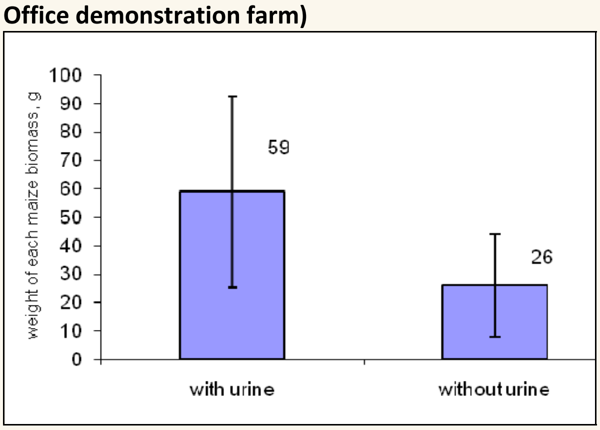

Figure 11: Weight of maize biomass (ROSA office), 175 kg N/ha equivalent of urine was added.

trial farm where there is big difference between the urine fertilized and unfertilized maize most probably because of the initial lower soil fertility. The maize yield fertilized by urine at a rate of 175 kg N/ha is seven times more than the unfertilized maize (Figure 10). The related maize biomass fertilized by urine is twice as much as the unfertilized one (Figure 11).

Figure 12: Control (left) and urine fertilized maize (right) at the ROSA office trial plot

A comparison of the results from the two trial plots shows the dependence of the effect of urine on the initial soil quality. Although the initial soil quality is not indicated here since it was not sampled, the Arba Minch University trial plot is very rich and it was in use as a farm while the farm in ROSA office is lacking nutrients and was not in use for agriculture before. The results of Arba Minch University farm trial plots also showed that the maize yield and biomass increased in response to the increased urine application, but at a slower rate at higher urine applications. Jönsson et al (2004) indicated that the effect of crop yield increases with increasing fertiliser application rates and then remains constant at higher concentrations.

From these two experiments, it is possible to say that less fertile soil has a tendency to give good yield with urine. Hence, the Ethiopian highlands, which are particularly suffering from nutrient depletion, are a promising region for using urine and compost conditioned with urine.

Impact of urine application on soil quality

Figures 13-15 show the soil quality changes after urine addition at the Arba Minch University trial farm plots. The conductivity of the soil increases with increasing urine application which means that there is a possibility of increased salinity as more urine is added to the soil (Figure 13). Farmers who are going to use urine as a fertilizer must irrigate with more irrigation water to leach the salt accumulation in the root zone of the plants. The dilution ratio can start from 3:1 urine to water and above. If 1 litre of urine is added either diluted with 25% or 75% the nutrients that are supplied to the plat are the same. The problem arises when concentrated urine is added salt is being accumulated on the soil surface and not reaching the plant root. Yet, when the urine is mixed with more water the nutrient may be leached or washed away before the roots absorbed it.

Figure 14 Kjeldahl nitrogen and potassium of soil fertilized by urine. The amount of nitrogen slightly increased with addition of urine which is one of the positive values of urine as a fertilizer. Potassium variation with increasing amount of urine was neglegible.

The pH of neat urine applied was about 9 (Table 2). The pH of soil measured after application of urine indicated in Figure 15 decreased with increasing application of urine on the soil. This might be described by as the fact that ammonium is nitrified in soil, releasing two protons and thus decreasing the pH. However, this might be only a temporarily

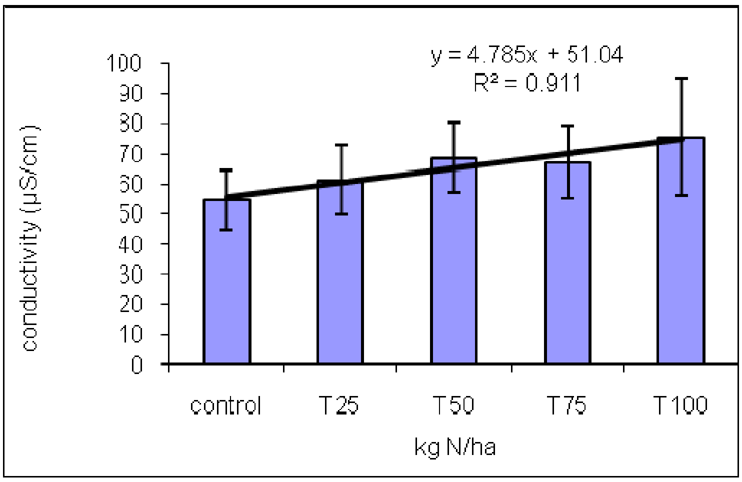

Figure 13: Conductivity of urine fertilized soil after harvesting maize

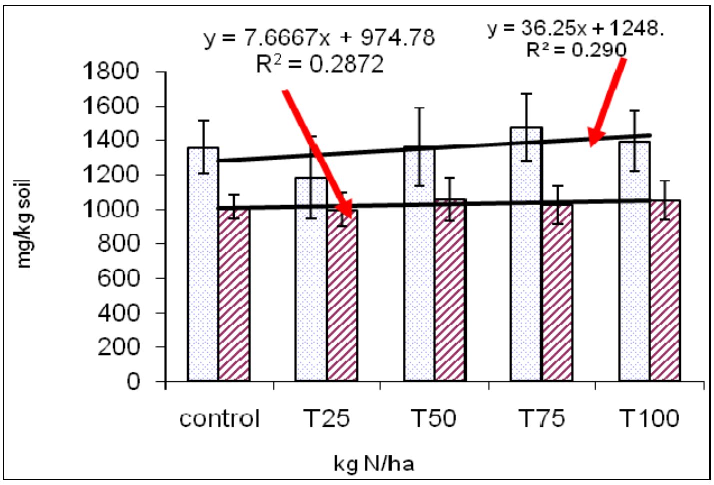

Figure 14: Potassium (filled) and TKN concentration (clean) in the soil fertilized with urine, after harvesting maize

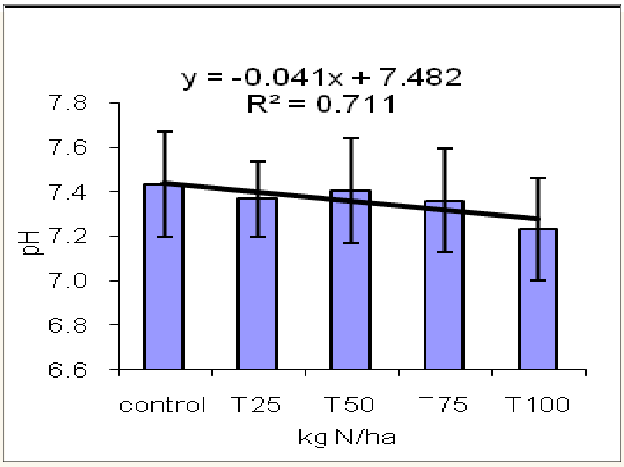

Figure 15: pH of urine fertilized soil after harvesting maize

effect since when nitrate is taken by plant root two hydroxide ions are released which this therefore result in the neutralization of the protons in the soil (Schönning, 2001). Then there might be no pH decline permanently in a soil treated with urine.

Conclusions and Recommendations

Urine collection, transport, treatment and reuse is one of the difficult step in resources-oriented sanitation systems because the society and the decision makers may not be aware of the advantages. In Arba Minch the transport and collection of urine from UDDTs was first done by car but gradually entrepreneurs were involved to independently transport by donkey cart without external support. This is a good progress to sustainability of the implemented sanitation systems.

Youth groups also use urine to enrich the co-compost, which they produce from faeces and organic waste. Costumers are happy to buy the produced compost so that the youth groups can gain an income.

The response of maize plant for urine is very good but it depends on whether the soil is already fertile in terms of nutrients or not. The response is very good in the ROSA office trial farm, while it is smaller at the University trial farm, where the soil had already a relatively high initial fertility.

Urine increases soil fertility but the development of soil salinity might happen especially in areas where irrigation water is scarce. Therefore, appropriate measures such as drainage might need to be taken and salt tolerant crops should be selected.
In order to make urine accepted by the Ethiopian farmers widely repeated research and demonstration should be done in different agro-climatic zones and preferably in cooperation with farmer associations.

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