Successful demonstration activities in the use of toilet compost and urine as a source of nutrients for growing crops.

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As the concept of ecological sanitation becomes more well known throughout the world, so does the need for adequate demonstration that the processed excreta, whether it be toilet compost, urine or a combination of both, is valuable and can actually play a useful role in increasing food production. Whilst the recycling of nutrients derived from human excreta is one of the main tenets of ecological sanitation, many if not most ecosan projects around the world concentrate first on the provision of an ecological toilet, mostly of the urine diverting type, with recycling the products taking very much a secondary place in project initiatives. In practice and perhaps in the majority of projects, both urine and dried faeces are more conveniently “disposed of” into shallow pits. Urine may drain away unused.

It must be accepted that not all users of ecological toilets are prepared to handle processed excreta at all – it is indeed a very foreign concept to most. Those who are prepared to handle the material are more likely to be “farmers” or “gardeners” and those that practice some form of agriculture already and already know the benefits of compost and manure. But even amongst this category, there is often doubt that urine and human manure is safe, let alone that it can actually increase the production of food.

Southern Africa is a sub-region characterised by a diverse range of peoples. The majority are poor with a much smaller proportion living under highly sophisticated conditions. For this reason a wide range of eco-sanitary hardware is used in the sub-region under the broadened umbrella of ecological sanitation, to cater not only for people accustomed to modern flush toilets, but also for those who may only have used the pit toilet before and in many cases no toilet at all.

The sub-region is also characterised by poor worn out soils, and unless they are fertilised or treated with manure, crop yields are often poor. Most people living in the rural areas will practice some form of subsistence agriculture and in several countries backyard agriculture is also practiced in both peri-urban and urban areas.

Where backyard agriculture is already practiced, commercial fertiliser or manure may be used to increase production, but an ever increasing proportion find these commodities either too expensive to buy or difficult to acquire. Under these conditions, the use of urine and compost derived from ecological toilets can actually make meaningful increases in production, both of vegetables and maize. Such practices can therefore have great practical value as well as forming strong links between the disciplines of sanitation and agriculture. And this of course is one of the most important aims of ecological sanitation. The back yard scenario is particularly suitable for the recycling of human excreta. In several countries in the sub-region, notably Malawi, Mozambique and Zimbabwe, backyard vegetable and maize production is commonly practiced, even in the urban and peri-urban areas. This is performed as a survival mechanism and perhaps because the forefathers have practiced it for generations. It is in such places there may be huge potential for wider scale on-site reuse of the processed excreta. It is also possible that with the new source of nutrient rich materials derived from the toilet, those formerly disinterested in backyard gardening may develop an interest.

Those living in highly populated urban areas may not practice any form of agriculture at all - the population density may be too high and the practice of back yard gardening may never have taken root. Where backyard agriculture is not practiced at all, either because space does not permit or because there is no history of growing food in this way, excreta derived from ecological toilets must either be disposed of into some nearby pit or removed on a commercial basis to be dumped or processed elsewhere. The very considerable quantities of urine produced must also dealt with in some way.

At the present time there is little knowledge, even amongst avid back yard gardeners in Southern Africa, of the potential of processed human excreta to increase food production. Perhaps this lies in the wake of an era when commercial fertilisers were promoted with great vigour, not only by industry but also by government. Even as the era of organic farming and permaculture takes route so does the potential for reuse of all organic materials. But it is true to say that even at thus time, organic farmers and those who practice permaculture caste eyes of doubt about the recycling of human excreta.

Thus there is at this time a need to adequately demonstrate and convince those that already practice some form of agriculture that there may be great potential in the re-use of processed human excreta, particularly in the back-yard environment. This paper describes a series of simple experiments where this increase in production of both vegetables and maize has been demonstrated and analysed in the backyard scenario.

Sources of nutrients

Urine contains most of the nitrogen produced in excreta and valuable amounts of potassium and phosphorus which are the main nutrients used in plant growth. Urine is collected in all urine diverting toilets and can also easily be collected in bottles, potties and other containers. Green vegetables and maize can benefit enormously from the large amounts of nitrogen found in urine.

Toilet compost can be collected from those urine diverting toilets where soil and ash is added to the excreta and where the mix is allowed to compost, either in the toilet vault itself or in a secondary compost site. Toilet compost can also be collected from shallow pit composters like the *Fossa alterna* where a mix of excreta (urine and faeces) together with soil, ash and preferably leaves too have been mixed and allowed to compost. Such compost resulting from this mix of ingredients can easy be dug out of shallow pits after a year of composting and mixed with topsoil. Trees also grow well on this material and planting trees on old compost pits offers perhaps the simplest method of recycling the nutrients in excreta. Fruit trees like banana and mulberry do particularly well. Toilet compost is less rich in nitrogen that urine, but it contains valuable amounts of all the major nutrients and is rich in phosphorus. It also adds humus and living material to barren soils. Dessicated faeces will also contain some potassium and phosphorus, but with minimal humus and living content.

It is not difficult to demonstrate the usefulness of toilet compost and urine on the plants commonly grown in the sub- region. In the experiments described below the source of toilet compost was the *Fossa alterna* a popular low cost eco-toilet in countries like Malawi and Mozambique. An analysis shows that, compared to many top soils, shallow pit toilet compost and composted faeces from urine diverting toilets contain valuable nutrients which plants can use.

Analysis of compost derived from urine diverting and pit composting eco-toilets

Soil source	pH	N*	P*	K*	Ca*	Mg*
Urine diverting toilet compost (faeces, soil, wood ash)	6.72	232	297	3.06	32.22	12.06
Fossa alterna* pit soil** ***Faeces, urine, soil, ash *(mean of 10 samples)*	6.75	275	292	4.51	11.89	5.14
Local topsoils (Harare area. *mean of 9 samples*)	5.5	38	44	0.49	8.05	3.58

Nitrogen (N) and Phosphorus (P*) are expressed as ppm and Potassium (K*), Calcium (Ca*) and Magnesium (Mg*) as ME/100gms. 1 ppm = 1 mg/kg.

1. Effect of enhancing vegetable growth by mixing toilet compost with poor topsoil

In a series of simple experiments vegetables like spinach, covo, lettuce, green pepper, tomato and onion were grown in 10 litre containers filled with very poor local topsoil and their growth was compared with plants grown in similar containers filled with a 50/50 mix of poor topsoil and toilet compost. In each case the growth of the vegetables was monitored and the crop weighed after a certain number of days growth. The following chart showed the results of these trials.

Plant and growth period.	**Weight at cropping Poor top soil only**	**Weight at cropping 50/50 mix topsoil/toilet compost**
Spinach. 30 days.	72 grams	546 grams (7 fold increase)
Covo. 30 days.	20 grams	161 grams (8 fold increase)
Covo 2. 30 days.	81 grams	357 grams (4 fold increase)
Lettuce. 30 days	122 grams	912 grams (7 fold increase)
Onion. 4 months	141 grams	391 grams (2.7 fold increase)
Green pepper . 4 months	19 grams	89 grams (4.6 fold increase)
Tomato. 3 months	73 grams	735 grams (10 fold increase)

2. Preparing and managing an eco-garden linked to an ecological toilet

In this case a small vegetable garden measuring 5m X 3.5m was prepared near an ecological toilet (*Fossa alterna*). The annual compost produced from the toilet was dug out of the shallow pit and piled in heaps over the garden and then mixed with the topsoil, thus enriching the soil. Treated and untreated sections were planted with rape and spinach and compared with a similar section not treated with toilet compost.

Plant and growth period.	**Weight at cropping. Existing vegetable garden. No. plants**	**Weight at cropping Existing vegetable garden + toilet compost. No. plants**
Spinach. 30 days.	2349 gms (24)	4153 gms (25)
Rape. 30 days	1928 gms (25)	2478 gms (23)
Spinach. Second 30 days	508 gms (20)	429 gms (19)
Rape. Second 30 days	622 gms (22)	576 gms (19)
Spinach. Third 30 days	170 gms (18)	172 gms (12)
Rape. Third 30 days	186 gms (14)	179 gms (14)
Total vegetable	**5763 gms**	**7987 gms (x 1.38)**

After 3 months cropping most of the nitrogen in the toilet compost had been used up. Carefully regulated applications of diluted urine can produce particularly good harvests of

green vegetables by the application of urine diluted with water (3:1 or 5:1) once or twice a week to the plants would increase the output further. These are described later.
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3. Toilet compost as a potting soil

Toilet compost (particularly from the ***Fossa alterna)*** can also be used as a good potting soil. Its relatively high level of phosphorus and moderate level of nitrogen is good for establishing seedlings and young plants. It is an excellent medium in which to plant maize and vegetable seeds, which grow well without extra feeding prior to the later application of urine (diluted in the case of vegetable and undiluted in the case of maize).

The compost is dug out, sieved to extract stones and other material and then added to seeds trays or small pots in which the seeds are planted. In the case of maize planting, a hollow is made in the topsoil and a measured amount of toilet compost (500gms) is added. The seeds are planted in this compost. Toilet compost is valuable and can be stored in sacks after being dug out of pits or urine diverting secondary composting sites.

4. The effect of urine application on growth of green vegetables

Several experiments have been undertaken with the effect of diluted urine on vegetables grown in containers. The effect is shown clearly here on Rape and Spinach, two popular green vegetables in Zimbabwe. It should be noted that those plants held in containers and water fed only will eventually use up most of the nutrients held in the limited volume of soil, whilst those regularly fed with nutrients derived from urine will flourish by comparison, as the plant food in the form of diluted urine is regularly supplied. Thus the effect of urine application in containers is more noticeable than plants grown in beds.

4a Rape

Rape is one of the most popular vegetables grown in Zimbabwe. It is used a great deal in relish eaten with maize meal in combination with onion, tomato and meat. It responds well to being grown in containers which are fed urine diluted with water. In this trial, rape was fed diluted urine (3:1) twice a week. The urine application led to a **5 fold increase** in harvest after 28days. This is an excellent response to urine.

Plant	Liquid plant food	frequency of application	weight harvested
Rape	water only	normal watering	160 gms (9 plants)
Rape	3:1 water/urine	0.5 litres 2 X per week	822 gms (9 plants)

4b Spinach

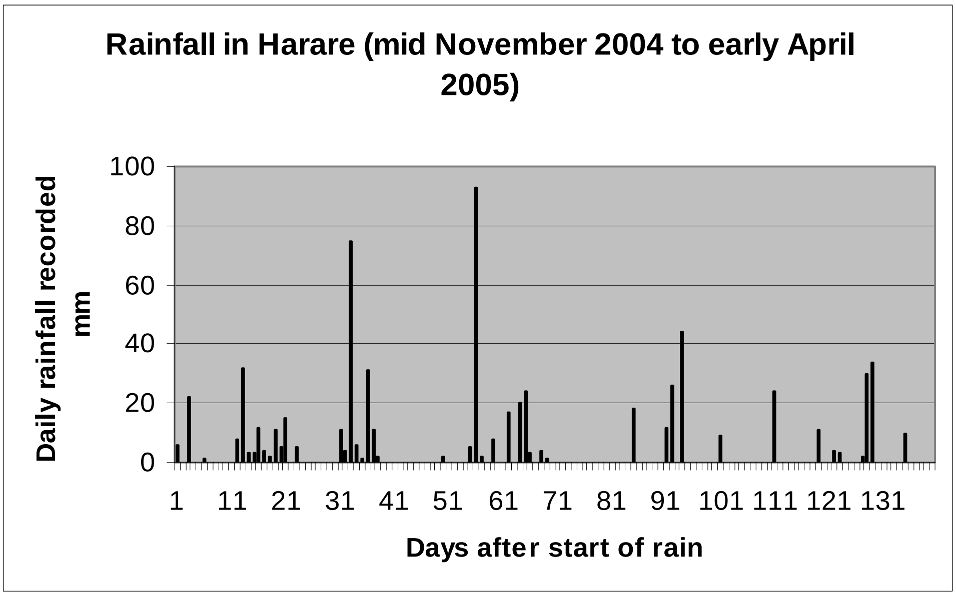
Like rape, several harvests can be taken from the same plant over a period of several months. It is ideally suited for growing in containers which are fed diluted urine as shown below. During the first month, the urine application (3:1, twice per week) led to a **3.4 fold** increase in harvest after 28days, compared to water fed plants. During the second month the urine dose should be reduced to 5:1, twice a week and during the third month and after, the urine dose should be reduced further to 5:1, once per week. 0.5 litres of the diluted urine is applied to each basin per treatment. The plants are watered at all other times.

Plant	Liquid plant food	frequency of application	weight harvested
Spinach (22plants)	Water only	normal watering	741gms
Spinach (22plants)	3:1 water/urine	0.5litres 2 X per week	2522gms

5. Effect of urine application on maize planted on poor sand soils

Maize is a vitally important crop in Southern Africa and it responds remarkably well to the application of urine (usually applied undiluted). Extensive trials have been carried out on the effects of urine on maize growth (Guzha (2004), Morgan (2002). The growth of the plant and the final size of the cob is closely related to the supply of nitrogen if all other factors like rainfall and sunlight are not restricting. With standard commercial fertilisation the seed is planted together with 10gms a general fertiliser known as compound D (1:2:1) which contains about 1 gm of N. A second application of ammonium nitrate, (containing 34.5% nitrogen). provides another 3.4gms of N, making a total of nearly 5gms. Sometimes more nitrogen is applied as the grain filling stage begins. For most people in Southern Africa who do not have a rich protein diet, the urine contains about 5gms per litre N (Håkan Jönsson pers. comm.). Thus one litre of urine provides about the same amount of usable nitrogen as a dose of standard commercial fertiliser. In various pre-field trials with growing maize on poor sandy soil in containers (not reported here), there was a close relationship between volume of urine applied and final cob weight. More urine – larger cobs.

Also various experiments both in containers and in field conditions have shown that on porous sandy soils this one litre of urine is best applied in a series of smaller applications to avoid losses of nitrogen due to leaching following heavy rain during the active vegetative growth and grain filling stages. The rainfall pattern in Southern Africa is often characterised by heavy storms followed by lengthy periods without rain, as the graph below shows.



Applying urine

A urine applicator made from a pill bottle with 125mls capacity was used in both backyard and field trials. The first 125mls was applied on planting day (day 0) under the seed (the seed is planted in 500gms of toilet compost). Further applications of 125mls urine were applied 0+3, 4, 5, 6, 7, 9, and 11 weeks to make a total of 1000mls.

Field Trial with maize in Epworth

Epworth is a large peri-urban settlement of about 200,000 people close to Harare. It was chosen as an experimental site to demonstrate the effectiveness of urine as an alternative to commercial fertilizer for maize production because it is characteristic of the conditions under which millions of people live both in peri-urban and rural areas in Southern Africa. Natural

Epworth topsoil is sandy, porous, almost without nutrients and applied nutrients can easily be lost by leaching during heavy storms. Without commercial fertilizer or manure, maize and vegetable crops are generally very poor on soils of this type. However despite this backyard soil in Epworth is characteristically patchy with variable nutrient level. This is because over the years sections of land have been fertilized with manure and compost, particularly in delineated vegetable gardens. Also there is some fertilization of maize crops for those who can afford to buy. So there is some carry over of nutrients from year to year.

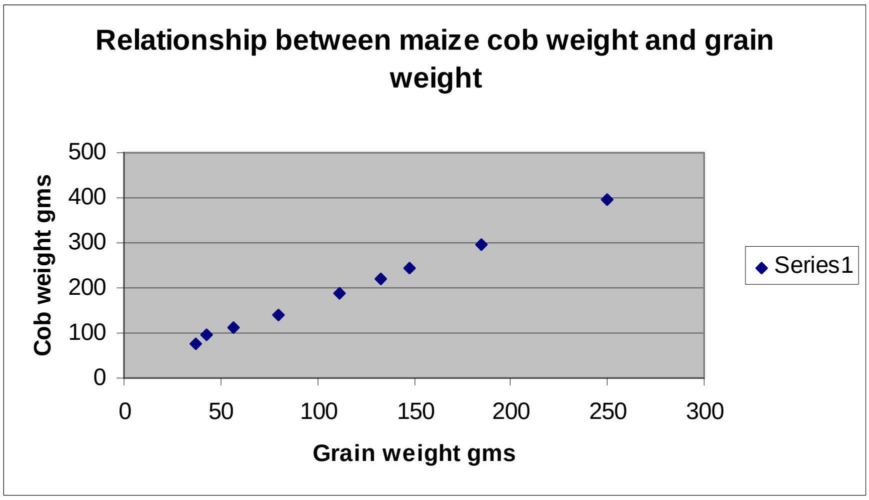
In the current trial a small existing backyard maize field was chosen which also housed an ecological toilet **(*Fossa alterna*).** 200 maize were planted and treated with a total of one litre urine during the vegetative and grain filling stages (as indicate above). A further 40 plants were not treated with urine. 40 additional plants were treated with standard fertilizer. At harvesting and for comparison a small sample of cobs was also taken from an adjacent field where no treatment of any type had taken place. Seed was planted in mid November and cobs harvested in mid March a period of 4 months.

Results

There was much variation between individual plants in all sections (apart from field 2) of the trial, mainly due to the variable existing nature of the soil even within each section of the experimental field, and probably due to earlier applications of manure, compost or fertilizer. This variation is characteristic of such fields and gardens. This variation was less evident in the urine fed section, where the treatment had a significant effect on maize growth and cob size – with more consistently larger cobs.

Section	No. Plants	Mean cob Wt. (gms)	Equivalent grain wt. (gms)
Untreated (field 2)	15	82.4	41
Untreated (field 1)	36	138.11	75
Treated: commercial fertilizer (field 1)	34	166.97	97
Treated: urine (1 litre per plant – field 1)	196	243.11	148

Overall mean cob weight was increased by 1.76 times (138gms to 242gms) by urine application when compared to the untreated section. When plotted against grain weight, this increase in cob weight (X 1.76) represents a doubling in the yield of grain. When plotted on a graph, a 138gm cob yields 75gms of freshly stripped grain compared to the larger 243gm cob which yields 148gms of grain.



The relatively high mean for untreated maize (field 1) was probably due to a sub-surface bed of manure or compost in one patch of the control zone which promoting healthy growth of a few plants making up 27% of the total cob weight in this section. The mean cob weight of urine treated maize (243gms) was about three times the mean cob weight (82gms) of sample cobs taken from another untreated field nearby, more typical of the area, where cob weights were more consistently poor. In terms of grain weight this is an increase of four times.

The urine was produced by the family itself and probably contained about 5gms/litre nitrogen, approximately the same as the nitrogen applied with commercial fertilizer. Residents in the area were impressed by the effect of urine treatment, which was plainly visible and cost nothing, but did require effort on the part of the householder. **Put in simple terms the treatment of individual maize, planted on poor sandy soils, with one litre of urine spread over the growth period resulted in a doubling of grain output.** This must be seen as a result worth the effort in such conditions.

The response of the maize in this trial to commercial fertilizer was surprisingly (and uncharacteristically) poor, with only a 1.2 times increase in mean cob weight. This may have been due to the very poor and irregular rainy season characterized by single heavy storms followed by long periods without rain. Under these conditions soluble nitrogen (from urine or ammonium nitrate) may be quickly lost into deeper soil by leaching in these porous sandy conditions. The more regular weekly application of urine, undertaken in this experiment, appears to have partly overcome the leaching effect.

Comparisons with maize growth in more fertile soil

For comparative reasons a similar trial was undertaken at the Friend Foundation in Tynwald near Harare. In this case a plot was chosen where animal manure (mainly donkey and dog) had been previously added to the soil over a period of time. This may be similar to a field or garden where kraal manure has been regularly added. This had the overall effect of enriching the soil, although the enrichment can be patchy.

Area 1 of the plot was planted with 70 maize which were treated with 1000mls of urine, applied over the growth and grain filling period in 5 applications. The seed was planted in 500mls of toilet compost. Area 2 of the plot was planted with 50 maize in toilet compost with a single 125ml application of urine. Area 3 of the plot was planted with 70 plants which were not treated with toilet compost or urine. The remainder of the plot (area 4) was planted with maize growing on manure treated soil without any further addition of urine or toilet compost. Maize was planted on 6th December 2004 and reaped on 24th March 2005. In each area the weight of each cob was measured. In area no. 4 which was the largest, a sample of 20 plants were measured. The results are as follows.

Area	**Additional Treatment**	**total wt cobs (no.)**	**mn.cob wt.**
1	toilet compost + 1litre urine	24 354gms (68)	358.14
2	toilet compost + 125mls urine	18 050gms (51)	353.92
3.	Original manure only	13 457 (66)	203.89
4.	Original manure only	6 708 (20)	335.40

Discussion

Under conditions where the soil is already enriched with manure, the presence of toilet compost and urine appears to have made little difference to the overall growth of the maize plants and final weight of cobs. The patchiness of the general area in terms of soil fertility is revealed by the differences in cobs weights from areas 3 and 4, neither of which were treated with either urine or toilet compost. The fertility derived from the manure enriched soil appears to have overridden the effects of toilet compost and urine in this experiment, where the application of either 1000mls urine or 125mls urine made little difference to the final yield of plants. The experiment also revealed that even within a small plot or field there can be much variation in the growth of maize plants depending on the nature of previous additions to the soil over localized areas. This was also revealed in the maize trial undertaken in Epworth.

In terms of cob size harvested, those from Tynwald were considerably larger than those from Epworth. The overall size of cobs harvested from all areas in the Tynwald soil was 305gms (overall mean) considerably larger than the overall mean of 211gms harvested overall from Epworth. This is entirely due to the quality of the soil in which the plants were growing and the fact that Tynwald soil had far more humus and was able to retain water better than the sandy soil of Epworth. Maize plants treated with one litre urine in Epworth had an overall mean size of 243gms compared to 358gms in Tynwald. These simple experiments also reveal that the overall effect of urine on the growth of plants is not only related to the amount of urine applied, but also to the quality of the parent soil. The poorer the soil, the more noticeable the effect.

The real test of the practicability of this type of treatment comes during subsequent growing seasons following the demonstration. Will the urine treatment method be repeated and copied by others? For a small maize field of 200 plants a total of 200 litres urine was required and the man and wife of the household coped with this production during the period of the experiment. But if larger numbers of maize plants were treated in the same way, collection and storage of urine would need to take place prior to the planting of maize. Urine can be stored in 20/30 litre plastic containers. Whilst the cost of these containers would be high initially, their use would continue over many years, making the overall investment worth while.

Growing maize in containers using a similar regime.

It is also possible to produce excellent table sized maize cobs by growing each plant in a container like a 10 litre bucket. Plastic bags can also be used to contain the soil and plant. 125mls undiluted urine is applied on planting day under a 500gm plug of toilet compost in which the seeds are planted. Further applications of 125mls of urine are made on a weekly basis after 3 weeks of growth from planting. In this case the total application of urine was 1500mls per plant, but a similar result might have been produced by the application of 1200litres. The mean cob weight for treated plants was 302gms compared to 112gms for an untreated plant (no urine). This is well above the mean cob size for urine treatment in the Epworth field. Perhaps urine application is more efficient in containers. The largest treated cob weighed 397gms yielding 250gms of grain. This compared with 50gms of grain produced from the untreated cob – five times the weight. A well worthwhile increase of food.

Overall Conclusions

These simple experiments and demonstrations show very clearly that both toilet compost and urine can have considerable value in enhancing the yield of both vegetables and maize – the most important components in the diet of most people living in Southern Africa. This is particularly the case where plants are grown on poor soils, which are common in Sub Saharan Africa. The toilet compost and urine are best used in combination, each providing special benefits. The greatest value of the toilet compost is its living component, which can bring beneficial organisms of various types to a dead and worn out soil, and also to its humus like properties, which helps retain water and also to the valuable supply of phosphorus as well as other important elements. The greatest value of the urine is its generous supply of nutrients, particularly nitrogen, which can increase the yields of green vegetables and maize in a spectacular way.

The experiments described in the paper are of the simplest type. They fall within the realm of bucket-science - literally! They are easy to replicate and demonstrate. Planting hardy plants like spinach in containers and applying urine to some and water to others quickly demonstrates the beneficial effects of urine. It is the demonstration of the effect which most impresses those yet to be convinced.

Simple as the experiments are, the implications are considerable. At its best the application of toilet compost and urine to the most important food plants of the sub-region on the worst of soils can lead to significant increases of harvest, particularly in the back yard garden scenario. In a continent where the majority live on poor soils and are also hungry – such considerations must be taken seriously.

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