An Ecological Approach to Sanitation in Africa

A compilation of experiences

Peter Morgan

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9. The Eco-toilet and agriculture

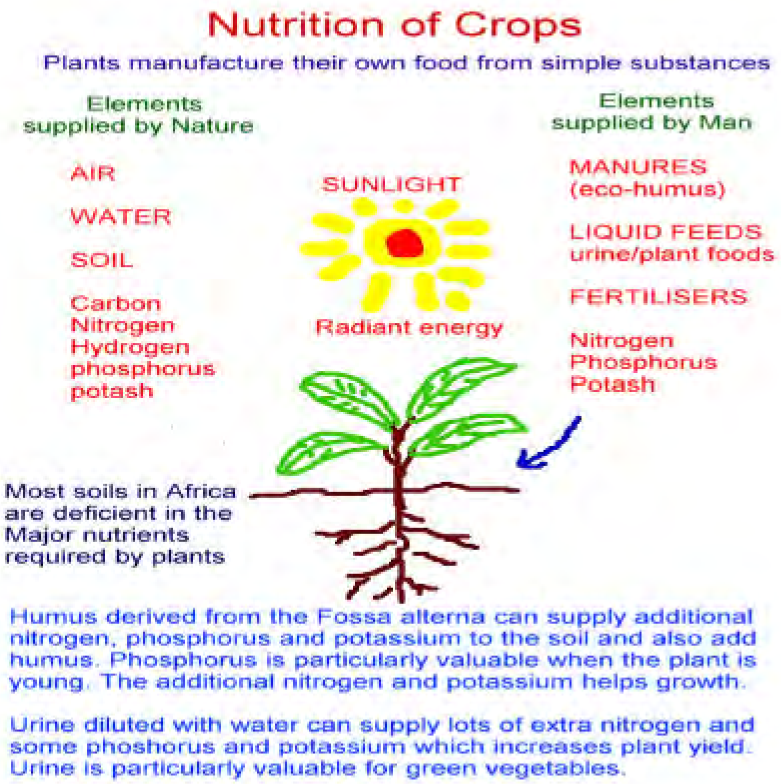
So far we have talked about toilets – how they are built and managed. We have arrived at the point where, in the Arborloo, we have a pit filled with composted excreta and soil etc ready for tree planting. In the case of the Fossa alterna we have arrived at the point where we have a pile of fertile humus which has been excavated from the shallow pit after a year of composting.

But at that stage we have only reached the first part of our story The best part is still to come! We must now plant trees to make use of the nutrients in the Arborloo pits and also use the Fossa eco-humus (and urine) to best advantage to grow better crops of vegetables.

The simple eco-toilets described here fit in well with the sound principles involved with organic gardening where organic materials of many types, like composted kitchen and garden wastes and animal manure etc, are recycled for the benefit of food and tree production. The use of eco-humus derived from human excreta is an extension of this idea, and there is nothing particularly new about it. Human waste, suitably composted, has been used by Man for a long time.

The importance of nutrients in plant growth

Plants require certain chemical elements for plant growth – these are called plant nutrients. Most of these are non-mineral elements such as carbon, hydrogen, and oxygen. These elements are mainly taken up as carbon dioxide from the air and water by the roots. Sunlight also plays a major part. Increasing the supply of sunlight, carbon dioxide and water through photosynthesis also increases the growth rate and crop yield of plants.



The nutrients are classified in two groups, macronutrients and micronutrients. The major uptake by plants falls in the macronutrient category. Macronutrients include nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg). These nutrients are mainly taken up from the soil by the plant roots in ionic form. Micronutrients include boron, copper, iron, chloride, manganese, molybdenum and zinc.

Each major nutrient, nitrogen (N), phosphorus (P) and potassium (K) plays a different role in plant growth and development. Each also plays a vital role, and plants grow best when there is a good balance of these essential nutrients. It is useful to record here the value of the different nutrients in plant growth and development.

NITROGEN

Increases size of leaves
Increases rate of growth
Increases final yields
TOO LITTLE - Poor pale green or yellow leaf
TOO MUCH - Delays ripening, causes lush but soft growth. Can block uptake of potassium.
VERY GOOD for green leafy crops and maize

PHOSPHORUS

Stimulates early root and shoot growth
Hastens leaf development
Encourages early maturity
TOO LITTLE - Poor growth
TOO MUCH - No harmful effect
VERY GOOD - All plants need generous supply

POTASSIUM

Improves health and quality of crop
Encourages fruit production
TOO LITTLE - plants less healthy and poor fruit production
TOO MUCH - Few harmful effects
VERY GOOD for potash-responsive crops like potatoes, tomatoes, tree fruits & legumes

- **Nitrogen** (available as nitrate) is the most important nutrient involved in vegetative plant growth and leaf building – it also helps to increases the final yield of crops. It is required in relatively large amounts. Plants deficient in nitrogen have pale leaves and look weak and the lower leaves gradually turn yellow, as the plant transfers the vital nutrients to where they are most needed in the formation of new leaves. However nitrogen cannot do its work unless phosphorus, potassium and other elements are also present in the soil in sufficient quantities. An excess of nitrogen can also reduce the uptake of other important nutrients like potassium which is important for the general health, fruit formation and disease resistance of plants. Most soils in Zimbabwe and surrounding countries are very deficient in nitrogen. Nitrogen is quickly washed out of the soil after heavy rain or watering, and needs to be replaced fairly often.

- **Phosphorus** is important because it gives a good start in life for plants by assisting strong root growth and shoot formation. It is also a good fruit builder and encourages early maturing and ripening. It hardens stems and vegetative growth and increases resistance to disease. Unlike nitrogen, which is easily flushed out, it is held by the soil and does not need to be replaced so often. Also unlike nitrogen and potassium, it does not burn plants. Generally phosphorus is deficient in most top soils in this part of Africa. A deficiency in phosphorus results in poor root growth which is revealed later by slow plant growth in general. One indication of deficiency is the purpling of leaves. There is seldom an excess of phosphorus in any soil. It is a very precious mineral in short supply unlike nitrogen which is available in abundance and potash which if needs be can be taken from wood ash. Most soils in Zimbabwe and surrounding countries are very deficient in phosphorus.

- **Potassium** (potash) builds fibre & skeletal growth in the plant and also helps to promote good fruit development. It promotes the general vigour and health of plants. A balance must be maintained between potassium and nitrogen as they interact with each other. Many important plants are "potash hungry" like tomato, potato, onion, runner bean – so potassium is important in our story. Potassium is not washed out of the soil as easily as nitrogen but is not held as strongly as phosphorus. Most soils in Zimbabwe and surrounding countries are very deficient in potassium.

Most garden fertilisers have a balance of nitrogen, phosphorus and potassium for use on vegetables. The ratio of the "NPK" in fertilisers, with phosphorus predominating, indicates that on the phosphorus deficient soils in Zimbabwe, most require more phosphorus than nitrogen overall. As the plants mature, more nitrogen may be required. Most leafy vegetables respond very well to the application of nitrogen after they have become established and this is available in large quantities in urine. Fruiting vegetables and root crops require far more potassium as they mature, and an excess of nitrogen may retard fruit growth, favouring lush leafy development. But each vegetable or crop has its own specific requirements. Also different soils vary greatly in what nutrients they can naturally provide for the plants. So the application of ***Fossa*** humus and urine to plants may result in a variable reaction, depending on the soil used and the type of plant grown. The ***Fossa*** humus improves soil texture and a good balanced supply of additional nutrients to the soil and most plants respond very favourably to its application.

Fruit and trees.

All plants have the same basic requirements, whether they are vegetables or trees. Thus in the early stages of a tree's growth, phosphorus will be required for good root and early shoot growth. Nitrogen once again will be required for vegetative growth. But fruit bearing trees do require plenty of potassium to produce of their best. Perhaps this is why young tree grow well on composted human excreta – it does contain generous supplies of phosphorus.

All fruit trees need adequate fertilisation to produce their best yields. Feeding of some sort is required every year, with manure, compost, diluted urine or other fertilisers. The amount of plant food required increases as the tree grows larger. In the case of citrus trees about 10 kg of manure or compost is required per tree per year for the first two years. This increases to 15 kg in the 3rd year, 20 kg in the fourth year, 25 kg in the 5th year, 30 kg in the 6th year, 35 kg in the 7th year, 40 kg in the 8th year and 50 kg between the 9th and 14th years. 10 kg is a wheelbarrow full or 150 gms ammonium nitrate, 200 gms single super-phosphate and 200 gms potassium chloride. For guava about 15kg manure or compost is required in the first year, 20 kg in the second and 45 kg from then on. Similar amounts are required by mulberry and avocado. Mango requires 10 kg manure or compost spread out through the year during the first year, 16kgs from the 3rd to 4th years, 18kgs for the 5th and 6th year and after 11 years about 60 kg. For Bananas about 15 kg manure or compost are required every year for each banana clump.

In ecological sanitation, the ***Arborloo*** is the closest link between the toilet and the tree. The nutrients present in the composted excreta, will be enough to start the tree off and a good quantity of phosphorus will be present and sufficient nitrogen and potassium to feed the tree for a year or two. The analysis of compost from a few ***Arborloo*** pits and from those ***Fossa alterna*** pits analysed (see below) show that even after a year of composting the nutrient level is high. Once the tree is planted, the nutrients held within the pit compost will start to be used up. So after two years, annual feeding of the fruit trees will be required to gain the best fruit yields. Urine can supply plenty of nitrogen, but less potassium. So the best way of applying urine is to dilute the urine (5:1) and add wood ash. The exact amounts required are still being worked out. As the tree grows larger, more will be required. A single charge in a watering can will be a mix of 2 litres urine to 10 litres water with a mug full of ash added and stirred in. Once the young tree is 2 years old, a mix of 2 litres, urine diluted with 10 litres water with a mug full of ash mixed in can be applied twice a month during the rains and with additional watering at other times. As the tree grows much larger quantities are required. It is important to keep the level of potash high in relation to nitrogen for best fruiting. The annual application of manure or compost will also help to sustain fruit output from trees.

Soil pH

For most crops the pH of the soil is best at a value of around 6.0 to 6.5. That is just slightly acid. At such a pH bacteria of the helpful kind will enjoy good conditions. The various soil nutrients will be kept in an optimum state of availability, various fungi that cause disease will find unfavourable conditions and the soil will tend to granulate to a more favourable size. If the pH drops too much below 6.5 or 6.0 then phosphoric acid ceases to be available. If the pH goes up to high, that is towards alkalinity, then certain trace nutrients will become entirely unavailable eg manganese, iron, copper, zinc, boron, and such a condition would be very hard to correct. There is therefore a serious danger in the over use of lime.

Special requirements

We have already mentioned that some plants require increased amounts of certain nutrients to give their best yields. All young plants require generous phosphorus and perhaps that is why the amount of phosphorus available in most general fertilisers contains more phosphorus than the other main nutrients. ***Fossa alterna*** humus does contain quite a generous supply of phosphorus. Most green vegetables and maize respond to a good supply of nitrogen, and diluted urine has much nitrogen. Indeed most plants respond positively to diluted urine if applied carefully during their main phase of vegetative growth. Several important plants like tomato, onion, potato and some types of bean need more potassium to give their best yields and this can be supplied by applying wood ash. Wood ash can also be applied in a liquid feed with diluted urine, or with water. Alternatively a liquid feed made from composted leaves in which comfrey leaves are included provides a good mix of nutrients including potassium. Most plants respond positively to soil to which compost has been added. As the plants use up nutrients for their growth, the soil requires replenishment, from whatever suitable source is available.

Nutrient levels in pit compost

It is interesting to record that the balance of available nutrients in humus derived from the pit compost (***Fossa alterna)*** is well spread between nitrogen, phosphorus and potassium, as they would be in commercially available general compound vegetable fertilisers. By comparison, urine has a very high level of nitrogen in relation to both phosphorus and potassium. Thus the effect of applying urine is much like applying a rich nitrogen fertiliser. Urine is particularly useful for promoting the growth of leafy vegetables like rape, covo and spinach, once they are established. Maize also responds very positively to the application of urine.

Soil analysis of ***Fossa alterna*** humus shows it contains much higher levels of the main plant nutrients than topsoil collected from a number of sites around Harare. These analyses are described in more detail in the next chapter.

Summation of levels of nutrients in *Fossa alterna* soil compared to local top soils

Soil source	pH	N	P	K	Ca	Mg
Mean value (local soils)	**5.5**	**38**	**44**	**0.49**	**8.05**	**3.58**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**	**11.11**	**5.61**

Conclusions

These various results show that the ***Fossa alterna,*** when well managed, offers the family a valuable asset, which is not only an effective toilet system, controlling both flies and odours, but also provides an excellent source of humus for the vegetable garden. Soil analysis reveals why the addition of humus derived from the ***Fossa alterna*** pit every year helps to enhance the fertility and nutrient levels of an existing vegetable bed. This can greatly enhance back yard vegetable production (see plant trials later). By combining these advantages with its low cost and relative ease of use and management, the ***Fossa alterna*** may hold much potential for future use in many parts of Africa. Since the same ingredients are also added to the ***Arborloo*** pit, it is logical to suppose that young trees will also gain much benefit, in their early life. Many generations of experience in countries from all over the world can vouch for the improvement of tree growth in old toilet pits. Even the Pilgrim Fathers used the idea when they arrived in the New World. The same method is practised in many countries in Africa today. The ***Arborloo*** concept is an extension of a well established and widely used traditional method. The formation of humus by mixing soil, leaves and excreta was invented by Nature itself.

Abundant growth of green vegetables in backyard garden enriched with contents of *Fossa alterna* pit compost.

10. The value of Fossa alterna compost

The unique challenge of the ***Fossa alterna*** is to achieve the conversion of human excreta held in a shallow pit into a relatively safe and valuable compost within 12 months. The ***Fossa alterna*** pits have been designed so they take 12 months or more to fill when used by an average family of about 6 persons. So a balance is struck between the rate of filling and the rate of conversion. The rate of conversion must take place in a shorter time than the rate of filling. If this can be achieved then a true alternate use of the twin pits can take place indefinitely. Most families of about six persons will fill a 1.2 meter deep pit (cross section 1m X 0.7m – total vol. approx 0.84sq.m.) in 12 months or more with a combination of faeces, urine and paper (anal cleansing material) together with soil, wood ash and leaves. Thus in the family unit, it is essential that the conversion of raw excreta into a pleasant humus must take place within a 12 month period. Against this challenge, one must not forget that in a normal deep latrine pit, the conversion of excreta into humus may take several years. In a fully lined pit latrine observed by the writer in Maputaland, South Africa, very offensive material remained 8 years after the pit had been abandoned. However in Malawi, the contents of pit latrines have been excavated 5 years after the pit had been abandoned and used to fertilise trees and crop. In the latter case the excreta was in close contact to the soil in both the side walls as well as the base of the pit, since, unlike the South African example, the pit was unlined. This would have helped the conversion a great deal, even in the absence of extra soils and compostable materials like leaves being added to the pit.

The conversion of excreta into humus in such a relatively short space of time becomes possible simply because extra ingredients are added to the pit contents which promote the formation of humus. Also simplicity is of the essence - hence the use of the drop and store method as in the pit latrine. A complicating factor is that urine is added into the pit and this must either be allowed to drain away or better still combine with the dry soil and leaves added and hence improve the nutrient level of the material formed within the pit. In practice some urine will drain away from the pit, but some will be retained in the forming pit humus. For this reason the volume of soil and ash added to the pit must be about equal to the volume of solid excreta added - a small mug full after every deposit of solids. To improve the texture, speed of conversion, as well as the nutrient level of the final product - it greatly helps to add leaves to the pit from bottom to top. Leaves should be added in plenty to the base of the new pit, during filling and also at the closing off stage.

The ideal combination of pit contents in the ***Fossa alterna*** is faeces, urine, paper, fertile soil, wood ash and leaves. This combination was first used in the prototype built and tested in Woodhall Road, Marlborough, Harare in 1999 (see *Ecological Sanitation in Zimbabwe*. Vol.1). The excreta occupied about half the volume of the experimental pit (the remaining half being soil and leaves) which had a total occupied capacity of about 212 litres (the pit was quite shallow). A pleasant humus-like material was formed within 4 months and excavated by the writer and used in various ways in the garden. Since that time large numbers of ***Fossa alterna*** pits have been excavated and their contents recycled.

Factors which will assist the conversion of excreta into humus within shallow pits include:

Adding plenty of soil and wood ash to the shallow pit after defecation
Adding dried leaves to the pit base before use, during use and at closure
Adding fertile top soil if possible
Trying to ensure good pit drainage
Observing the pit filling rate & spreading out pit contents as the pit fills
Using at the family level (ie not overusing)

The use of the ***Fossa alterna*** demonstrates how effective the soil can be as a converter of human excreta into "humus," using the myriad of naturally occurring beneficial bacteria present in the soil itself. The addition of wood ash to the mixture also assists by acting as an absorbent of moisture, increasing the potash component and also making the reaction slightly more alkaline, which may help the biological process. Wood ashes also reduce odour and helps to control flies. The addition of leaves to the mix helps the composting process considerably by improving amount of air in the mix and adding the fungae and bacteria which help to break down leaves. The addition of leaves, not only improves the physical characteristics of the resulting humus, making it darker and more crumbly but also adds extra plant nutrients. An analysis of leaf mould, formed from composted leaves is also provided in this chapter, and reveals how valuable composted leaves can be a source of plant nutrients. Thus it makes sense to add them to the pit, as well as soil and ash, thereby improving the overall nutrient level and the final crumbly, water retaining properties of the humus. Plants grow best in soils which are fertile, crumbly, hold water and where there is a living, biological content.

Nutrient levels in *Fossa alterna* "humus" - an analysis of soil

After one year of composting in a shallow pit a mix of human excreta, soil, ash and leaves will completely change into a pleasant smelling humus. However this ideal mix may rarely be achieved in practice – at least at first. It is most likely that any poor surrounding soil will be added rather than a mix of soil, ash and leaves. Even in the ***Fossa alterna*** toilets observed and tested by the writer, it was rare indeed that the ideal mix was added, the norm being soil alone with very few nutrients. Thus the data given below for soil nutrients in ***Fossa alterna*** humus are a result of the combination, not of the ideal mix, but of the mix which has resulted in practice - just soil and excreta. The results reveal however, that even when only poor soil and excreta are added and allowed to compost, the nutrient level in the resulting humus is high, and infinitely higher than either the soil that went into the pit or the surrounding soil.

The figures below show the pH and levels of nitrogen (ppm - after incubation), phosphorus, (ppm) and also potassium, calcium and magnesium (ME/100gms.) in twelve samples of the ***Fossa alterna*** taken from the Friend Foundation (10 samples), Epworth (one sample) and Woodhall Road (one sample), all in the Harare area. Later these figures are compared to various naturally occurring soils in Zimbabwe (in the Harare area) and also to samples of humus excavated from jars used to process faeces derived from the urine diverting ***Skyloo*** (see later chapter).

The soil analyses were performed at the Chemistry and Soil Research Institute of the Ministry of Agriculture, Harare. The nitrogen is analysed by the Kjeldahl method for Min N. ppm (initial) and Min N ppm (after incubation). Min N ppm (initial) refers to nitrogen immediately available to plants such as nitrate (N03) and ammonium (NH4). The soil is then incubated for 2 weeks, turning the organic nitrogen in the soil (living and non living) to inorganic nitrogen. This is tested again. The pre-incubation nitrogen is available to plants immediately and the nitrogen, after incubation, is available to plants throughout the growing season. It is the latter which is used to base recommendations for fertilisation and this has been used in presenting the data here. Phosphorus is analysed with the resin extraction method in which the soil is shaken with an Anion Exchange Resin that progressively absorbs the P as it comes into solution. Results, in ppm show available P not total P. The exchangeable bases (Ca, Mg, K) are extracted with ammonium acetate in a reaction where the NH4 ions replace these bases on the exchange sites of the soil. The concentrations are derived from analysis by the atomic spectrophotometer (Farai Mapanda pers.comm).

Examples of *Fossa alterna* soils

Most of the ***Fossa alterna*** soil samples analysed for major plant nutrients are a mix of human excreta and soil only (samples 1 – 10). In these early experiments the ideal mix of soil wood ash and leaves was never attained. Also poor soils were added rather than richer more crumbly soils. Thus the humus formed was of a very basic type of a lower quality, in the absence of ash or leaves.

The final quality of the eco-humus is much related to the type of soil added to the pit contents, and also whether leaves are added. Sandy soils will produce an "eco-soil" which has a sandy texture, grey soils turn into darker grey soils. Clay soils will result in a soil which is more clay like. Crumbly soils with good texture make the best eco-humus. The best eco-soils are made by adding a fertile top soil in combination wood ash and leaves. The leaves convert into leaf compost - and this is an excellent material for improving soil texture and also nutrient levels in the final product. What ever the soil added, the final resulting soil will be considerably improved in terms of nutrient levels.

Ideally fertile topsoil should be added to the pit, as this will have a higher content of both living organisms and nutrients, and lead to a more fertile humus being formed within the pit, compared to adding poor soil. However it is not always possible to find good topsoil near an eco-latrine, and the obvious procedure for the householder would be to add soil that is found nearby. This would normally be local topsoil with a low nutrient level. In the cases analysed below locally available topsoil was added to all the pits under study and never fertile topsoil. No leaves or ash were added to the Friend Foundation samples. Leaves and ash were added to the Epworth sample, as well as local topsoil. The Woodhall Road sample, which produced the darkest and most crumbly humus was a mix of excreta (urine and faeces), local topsoil and leaves (dried guava and avocado) only, without ash. It also converted into humus in the fastest time, no doubt due to the high air contents resulting from the addition of leaves throughout the depth of the pit. Leaves are valuable additions to the composting pits, like soil, and are best added prior to use, during use and in the final covering of the pit contents following closure.

NUTRIENT LEVELS IN *FOSSA ALTERNA* HUMUS

Soil source	**pH**	**N**	**P**	**K**	**Ca**	**Mg**

	pH	N	P	K	Ca	Mg
Sample 1. (Friend Foundation)	**6.5**	**269**	**317**	**1.59**	**20.77**	**11.28**
Sample 2. (Friend Foundation)	**6.1**	**246**	**330**	**4.64**	**5.53**	**5.41**
Sample 3. (Friend Foundation)	**6.6**	**174**	**374**	**3.74**	**8.59**	**5.74**
Sample 4. (Friend Foundation)	**6.2**	**222**	**422**	**2.22**	**3.60**	**3.57**
Sample 5. (Friend Foundation)	**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
Sample 6. (Friend Foundation)	**7.7**	**316**	**242**	**3.84**	**9.96**	**3.42**
Sample 7. (Friend Foundation)	**7.6**	**355**	**258**	**7.14**	**8.97**	**6.26**
Sample 8. (Friend Foundation)	**6.9**	**305**	**230**	**6.65**	**12.00**	**10.32**
Sample 9. (Friend Foundation)	**7.7**	**354**	**257**	**9.18**	**9.26**	**3.46**
Sample 10 (Friend Foundation)	**6.3**	**197**	**299**	**2.94**	**26.64**	**4.77**
Sample 11 (Epworth)	**7.1**	**240**	**194**	**2.80**	**5.22**	**3.65**
Sample 12 (Woodhall Road)	**7.8**	**285**	**228**	**2.80**	**9.24**	**2.33**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**	**11.11**	**5.61**

Enhancement of deposited soil

The quality of the humus derived from ***Fossa alterna*** pits varies depending on what extra ingredients are added to the pit in addition to excreta (urine and faeces). The texture, nutrient levels and water holding capacity, for instance, are improved if fertile topsoil and leaves are added in addition to the excreta. The texture of the excavated humus is similar to the soil added to the pit. However even when poor soil is added alone, significant improvements can be achieved in nutrient levels as the results below show. In the cases cited below soil analyses were made on the soil added to the pit as well as the soil (humus removed).

Example 1.

	pH	N	P	K	Ca	Mg
Soil added to FA pit (cemetery topsoil)	**4.9**	**50**	**13**	**0.18**	**2.95**	**0.78**
Humus removed from *Fossa alterna*						
Sample 4	**6.2**	**222**	**422**	**2.22**	**3.60**	**3.57**
Sample 6.	**7.7**	**316**	**242**	**3.84**	**9.96**	**3.42**

Examples 2, 3 and 4

	pH	N	P	K	Ca	Mg
Soil added to FA pit (kennels site. pit soil)	**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
Humus removed from *Fossa alterna*						
Sample 7.	**7.6**	**355**	**258**	**7.14**	**8.97**	**6.26**
Sample 8.	**6.9**	**305**	**230**	**6.65**	**12.00**	**10.32**
Sample 9.	**7.7**	**354**	**257**	**9.18**	**9.26**	**3.46**

Example 5 (Epworth sample 10)

	pH	N	P	K	Ca	Mg
Soil added to FA pit (Epworth topsoil)	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**

Note local dried leaves and some wood ash were also added to the pit)

	pH	N	P	K	Ca	Mg
Humus removed from *Fossa alterna*						
Sample 11 (Epworth)	**7.1**	**240**	**194**	**2.80**	**5.22**	**3.65**

Example 6 (Woodhall Road sample 12)

	pH	N	P	K	Ca	Mg
Soil added to FA pit (Woodhall Rd soil).	**6.2**	**27**	**32**	**0.63**	**9.68**	**2.30**

Note dried guava and avocado leaves were also added to the pit)

	pH	N	P	K	Ca	Mg
Humus removed from *Fossa alterna*						
Sample 12 (Woodhall Road)	**7.8**	**285**	**228**	**2.80**	**9.24**	**2.33**

Urine inclusion and urine diverting

In one experiment a urine diverting slab was placed over the pit. The resulting soil formed was compared to soil formed in a pit where both urine and faeces were added.

	pH	N	P	K	Ca	Mg
Soil added to *Fossa alterna* pit	**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
Humus removed from *Fossa alterna*						
Sample 1. (Urine inclusion)	**7.6**	**355**	**258**	**7.14**	**8.97**	**6.26**
Sample 2. (Urine diverting)	**6.9**	**305**	**230**	**6.65**	**12.00**	**10.32**

Note that levels of nitrogen, phosphorus and potassium are slightly elevated in the eco-humus in which urine and faeces are added compared to those in which urine is diverted elsewhere. However the difference was slight.

We can now compare the nutrient levels found in *Fossa alterna* humus and mixed soils with a series of samples taken of naturally occurring top soils taken in the Harare area.

Examples of naturally occurring top soils

Soil source		pH	N	P	K	Ca	Mg
Harare (Tynwald 1.)		**6.1**	**32**	**68**	**1.59**	**6.42**	**4.02**
Harare (Tynwald 2.)		**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
Harare (Marlborough Vlei)		**5.1**	**72**	**30**	**0.99**	**22.88**	**18.06**
Harare (Epworth 1**)**		**4.0**	**18**	**9**	**0.08**	**1.46**	**0.32**
Harare (Woodhall Road**)**		**6.2**	**27**	**32**	**0.63**	**9.68**	**2.30**
Ruwa (Knuth Farm 1. veld**)**		**7.5**	**30**	**30**	**0.12**	**3.79**	**0.56**
Ruwa (Knuth farm 2. pit soil)	**5.1**	**14**	**23**	**0.01**	**1.12**	**0.48**	
Ruwa (Knuth farm 3 - garden soil)		**6.7**	**96**	**143**	**0.73**	**15.23**	**1.96**
Harare (Epworth 2)		**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**
Mean value (local soils)		**5.5**	**38**	**44**	**0.49**	**8.05**	**3.58**

According to the Chemistry and Soil Research Institute, many naturally occurring top soils found in Zimbabwe reveal very low levels of nutrients available for plants. This is due to weathering, lack of tree cover, and the effects of rain on badly eroded soils. A nitrogen level in soil of less than 20ppm is regarded as low, 20 – 30 as medium, 30 -40 adequate and 40 plus is regarded as "rich". So the soils produced from the ***Fossa alterna*** are rich indeed, with those in our range of naturally occurring soils being in the adequate range.

For phosphorus, less than 7 ppm is regarded as low, 7 – 15 marginal, 15 – 30 medium, 30 – 50 adequate and 50 plus "rich." Thus once again the natural soils tested were in the adequate range. Once again the ***Fossa alterna*** humus is rich in P, which is a valuable component. It can be mixed with local top soils to get an enhanced production of vegetables, which is what this story is all about. Critical ranges for Ca are 15 – 20ppm, and 0.3 – 0.4 meq/100g for Mg and 10 – 15ppm for K.

The top soils of many parts of Southern Africa are worn out and almost devoid of humus or nutrients. In Zimbabwe 70% of rural farmers work on a soil which is labelled as poor or very poor, holding less than 42ppm of phosphorus. Nitrogen, phosphorus and zinc, amongst other minerals were seen as limiting to meaningful agriculture in 70% of samples collected around Zimbabwe. Most soils are sandy and have a low pH. Few soils in the rural and even peri-urban and urban areas can sustain any form of healthy crop production without meaningful inputs of both humus and nutrients (Farai Mapanda (pers.comm). Thus any form of fertile soil which can be locally produced and mixed with the poor local topsoil can only be seen as advantageous.

Basic comparisons

Mean value (local soils)	**5.5**	**38**	**44**	**0.49**	**8.05**	**3.58**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**	**11.11**	**5.61**

Mixes of *Fossa alterna* humus and other soils

Enhancement of nutrients by combining with poor soils

Fossa alterna humus, resulting from a mix of faeces, urine, paper and soil (and preferably leaves) can be mixed with less fertile soils to make a planting medium in which vegetables grow well without additional "fertilisers" being required (see later).

The following figures show how the ***Fossa humus*** can elevate the nutrient levels of very poor soil when a 50/50 mix is made between barren soil and eco-humus.

Example 1.

Soil source	pH	N	P	K	Ca	Mg
1. Knuth soil	**6.1**	**32**	**68**	**1.59**	**6.42**	**4.02**
2. *Fossa alterna* (orchard site)	**6.6**	**174**	**374**	**3.74**	**8.59**	**5.74**
Result of 50/50 mix mix .	**6.2**	**91**	**337**	**1.45**	**4.58**	**2.29**

Example 2.

1. Knuth soil	**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
2. *Fossa alterna* (1a site)	**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
Result of mix .	**6.4**	**91**	**247**	**0.88**	**3.05**	**2.49**

Example 3. (33/33/33 mix)

1. Woodhall Rd soil	**6.2**	**27**	**32**	**0.63**	**9.68**	**2.30**
2. *Fossa alterna* soil (FA1a site)	**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
3. Leaf mould	**7.4**	**540**	**266**	**9.00**	**291**	**12.90**
Result of mix	**6.8**	**331**	**294**	**2.10**	**12.14**	**5.85**

Example 4. (50/50)

1. Epworth soil	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**	
2. Fossa alterna (FA long site)		**6.3**	**197**	**299**	**2.94**	**26.64**	**4.77**
Result of mix		**6.4**	**78**	**356**	**1.01**	**15.75**	**1.78**

These figures reveal now the nutrient levels in poor soils can be enhanced considerably by mixing them with equal volumes of ***Fossa alterna*** soil, as would be expected, although the unusually high levels of phosphorus in the mixes of examples 2, 3 and 4, which exceed both poor topsoil and ***Fossa alterna*** soil, cannot be explained but appear to be consistent.

These figures show clearly how human excreta when mixed with topsoil can produce a “new soil” with significantly more nutrients than most naturally occurring top soils. Enough nutrients in fact to mix in equal proportions with existing topsoil or even at a rate of 2 parts local soil with none part ***Fossa*** humus to make viable vegetable production possible without further fertilisation (see later chapters). The results also show a good mix of nutrients with meaningful quantities of phosphorus and potassium as well as nitrogen. Thus the nutrients available in the humus are balanced more as they would be in commercially available compound vegetable fertilisers. However, the actual nutrient level in soil is not the only factor which helps plants grow well – and the physical condition of the soil, and its living content are also very important. The ***Fossa*** humus appears to provide both a physical improvement by providing humus together with a significant increase in all major nutrient as well.

What all these results show clearly is the significant level of nutrients held in human excreta. It is sufficient to change a worthless soil into one on which vegetables can be grown, if needs be, without further application of nutrients. Later chapters in this book describe how the eco-humus is best used in agriculture and also how urine can be used to enhance the effect even further particularly for leafy vegetables.

What these experiments also reveal is the very considerable value of nutrients which are daily taken to waste, both in standard sewered sanitation and also pit sanitation. In Zimbabwe alone, half a million Blair VIP Latrines accumulate approximately 250 000 cubic metres of human waste per year which remains unused. Had the use of eco-latrines of the type described in this book been introduced and adopted years ago, backyard vegetable gardens would surely have been more fertile.

The value of leaves as an additive of *Fossa alterna* pits.

Constant reference is made to the considerable benefit which can be derived by adding leaves to ***Fossa alterna*** pits. Leaves help the composting process considerably, by adding more air into the mix, and by adding a composting process undertaken largely by fungi to the already existing bacteriological process undertaken by soil micro-organisms.

During the first year of operation, the second pit of the ***Fossa alterna***, which must be built at the same time as the first pit, can be left empty and covered with a wooden lid. This will be the standard procedure. However it is possible to take advantage of the second pit during the first year of operation. One of the best methods is to make leaf compost within this pit for the first year of operation.

At one site in Epworth close to Harare, leaves were gathered and emptied into the pit interspersed with thin layers of the local topsoil. Water was added from time to time. After 12 months the leaf compost was excavated and proved to be much richer in nutrients than the original soil. In fact plants grew in this leaf mould far better than in the original soil. The second pit acted like a pit composter and was well worth the simple effort involved of adding leaves, soil and water. The following table shows the increase of nutrient levels in the leaf compost made in the second pit compared to the local topsoil. The figures below show the pH and levels of nitrogen (after incubation), phosphorus, (ppm) and also potassium, calcium and magnesium (ME/100gms.) in the leaf compost formed in the second pit of a ***Fossa alterna*** compared to the surrounding topsoil which was added together with local leaves.

Soil source	pH	N	P	K	Ca	Mg
Local topsoil (Epworth)	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**
Leaf compost from second pit	**7.7**	**81**	**130**	**1.86**	**9.31**	**1.88**

Composted leaves clearly have a considerable nutrient value of their own and no doubt greatly enhance the final quality of ***Fossa*** humus, if added. The results of four soil analyses of leaf mould formed in wire baskets and a variety of containers is given below. A description of these leaf mould makers is given later in this book.

Analysis of leaf compost

Soil source	pH	N	P	K
Leaf compost in wire basket	**8.2**	**256**	**344**	**3.92**
Leaf compost formed in plastic bag	**7.8**	**267**	**294**	**8.50**

Leaf compost formed in steel drum	**7.6**	**239**	**255**	**0.60**
Leaf compost formed in brick moulder	**7.4**	**540**	**266**	**9.00**

Overall comparisons of soils and composts

Soil source	pH	N	P	K
Mean value (local top soils)	**5.5**	**38**	**44**	**0.49**
Mean value leaf mould	**7.75**	**325**	**290**	**8.00**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**

Physical properties of excreta, soil, leaf mixes.

One interesting property of excreta or mixes of excreta and soil, both in jars and pits is that the volume is considerably reduced over time. Even with abandoned full latrine pits the volume may decrease considerably over time. In urine diverting toilets the urine is channelled away and the faeces dehydrate or compost and loose their initial volume due to loss of moisture. In shallow pits the combination of urine and faeces also loose volume over time with the urine being absorbed into the soil added to the pit and also into the soil surrounding the pit. The bulk and volume of the faeces is also reduced over time with the liquid fraction of the faeces being absorbed into the soil added to the pit. It is known that the water content of the faeces is variable but always high. It is this larger water fraction of the faeces which can be absorbed into other ingredients added to the pit (soil, ash, leaves),whilst the remaining smaller solid fraction of the faeces is converted into humus, which forms part of the final total volume of the humus formed in the pit or jar.

But what are the fractions?

The following experiment was carried out to calculate the percentage water content of faeces by combining a known weight and volume of faeces with a known weight and volume of dry soil. Since the dry soil would loose neither weight of volume, any change in the final volume and weight of the mix would be caused by changes in the properties of the faeces.

A sample of faeces was collected in the ***Skyloo***. This sample weighed 357gms, had a volume of 340mls and a density 1.05 gm/ml. This was mixed with a near equal volume of dry soil with a weight of 352gms, a volume of 310mls and a density of 1.135 gm/ml. Therefore the total weight of the mix was 709gms having a volume of 650mls and an overall density of 1.084 gm/ml.

On the left, raw faeces and soil being mixed prior to composting. On the right a mix of leaves, soil and raw faeces prior to mixing and composting

This was allowed to slowly compost over a period of 24 days. Fly larvae developed in the mix, which also attacked by ants. Slowly the mix changed into soil. Another mix was made with an approximately equal mix of faeces, dry soil and crushed dry leaves. This mix was also allowed to compost for the same period. After the period of composting both samples were laid out in the sun to substantially dry out, but not to full desiccation status. The final weight of the dried soil/faeces mix was 420gms, with a volume of 405mls and a density of 1.037gm/ml.

Thus the weight of the "new soil" formed had increased from 352 to 420g (about 19%), compared to the original soil in the mix and the volume of the "new soil" had increased from 310mls to 405mls (about 30%) compared to the original soil in the mix. Since the volume and weight of the dried original soil cannot change, the faeces weight had therefore been reduced from 357g to 68g (420 - 352g) - 19% of original. So water content was 81%. The faeces volume had therefore been reduced from 340mls to 95ml (405 - 310ml) - 28% of original). So the final density of the mix was less than the original soil. The mix was also darker in colour. The overall initial combined wt of the combo was reduced from 709g to 420g) (59.23% of original). The overall initial volume of the combination was reduced from 650 ml to 405ml. (62.3% of original). The processed combination of "NEW SOIL" was very similar in appearance to original soil since 76.5% of its new volume and 83.8 % of its new weight consists of the original soil.

Samples of original soil (left), and "new soil" made from faeces and soil (centre) and from faeces, soil and leaves (right)

In the case of the faeces/soil/leaf mix a final weight of 270gms was measured with a volume of 405mls. This gives a density of the combination of 0.66gms/ml. This is a much lower density compared to the faece/ soil mix. **Clearly the addition of leaves lowers the density**, a result no doubt of the less compaction and more air in the mix due to the presence of leaves. These properties would encourage far more efficient composting. **Composting is far more effective as the air content increases.** This is a very important finding.

Density trials on *Fossa alterna* humus

The results shown above would explain why a mix of excreta, soil and leaves appears to compost much faster than a mix of soil and excreta only. To test this theory the humus taken from a ***Fossa alterna*** which had a mix of excreta, soil and leaves was compared to the humus taken from another ***Fossa alterna*** which had a mix of excreta and soil only. The initial comparisons (for volume, weight and density) were made in crumbly (not dried) ***Fossa alterna*** humus. These samples were then dried out in the sun to obtain new parameters.

***Fossa alterna* soil (crumbly, not dried)**

Soil /humus type	**Vol. ml**	**Wt.gm**	**density**
FA kia (excreta,soil,leaves)	410 (jam jar)	370g	0.90g/ml
FA FF (xcreta,soil only)	410	402g	0.98g/ml
Garden soil	400	443g	1/10g/ml

***Fossa alterna* soil (sun dried)**

Soil/humus type	vol. ml	Wt.gm	density
FA kia	325	278	0.85g/ml
Fa FF	370	338	0.91g/ml
Soil	368	392	1.06g/ml

These results reveal that where leaves are added to the ***Fossa alterna*** pit the resulting density of the humus is lower. The density of the humus is related to both the moisture content and the air content. The more air (with some moisture) the better the conditions for composting. Thus a mix of excreta, soil and leaf in the Fossa alterna pit is more effective and leads to a faster and more efficient composting process than the mix of excreta and soil alone. Interestingly it was this mix of excreta, soil and leaves which was tested in the initial ***Fossa alterna*** trial in 1999.

Leaves are an important ingredient in this process because the leaves provide extra nutrients to the mix, they provide extra air and improve soil texture. They add a process of fungal decay in the mix as well as composting based on bacteria. They also provide a larger surface area for the composting process to take place and allow for better pit drainage. All these combined beneficial effects of leaves enhance the composting process considerably.

Consequently the addition of leaves to the shallow pit composting process in both the ***Arborloo*** and ***Fossa alterna*** has been greatly encouraged. Similarly leaves are now added to the buckets holding faeces, ash and soil in the ***Skyloo*** and subsequent jar composters.

Adding leaves to shallow pits

Adding leaves to *Fossa alterna* pits. On left at Woodhall road, on right at Epworth. Adding dried leaves to shallow pits used in the *Arborloo* and *Fossa alterna* helps the composting process considerably.

Adding semi composted palm leaves to the base of a *Fossa alterna* pit in Mombasa, Kenya (left). Two sacks full of leaves at the base of a concrete lined pit in Maputaland, South Africa.

Conclusions

These various results show that the ***Fossa alterna,*** when well managed, offers the family a valuable asset, and well worth the initial investment. It is not only an effective toilet system, controlling both flies and odours, but also offers the family a simple and effective unit for making nutrient rich compost.

The annual production of humus, when mixed with poor local topsoil can enhance back yard vegetable production considerably (see plant trials later). By combining these advantages with its low cost and relative ease of use and management, the ***Fossa alterna*** may hold much potential for future use in many parts of Africa.

It must be remembered however that the annual output of compost from the family owned ***Fossa alterna*** is not large, possibly about 500 litres per family per year. So its value lies in enhancing food production on a small scale on the family vegetable garden and not on extensive fields. However such improved fertility will improve year by year and thus the back yard vegetable crop can be sustained.

Early experiments with the *Fossa alterna* Revealing the miracle of conversion of excreta into compost.
Ephraim Chimbunde at work. An early photo of a *Fossa alterna* in Epworth.

11. Methods of using "Fossa alterna" compost in the garden

This chapter deals with methods of utilising humus formed in the ***Fossa alterna.*** This humus is ideally formed as a result of composting of a combination of faeces, urine, good topsoil, wood ash and other vegetable matter like leaves. In practice however, until the best state of the art is reached, the ***Fossa alterna*** "humus" may only be a combination of faeces, urine and soil and the soil component may be poor. This results in a pit soil which has rather a poorer texture compared to a humus formed with good topsoil and/or leaves added. If this so called "humus" is a mixture of excreta and poor soil alone - is may not be really humus like at all. In texture it more closely resembles the soil that was placed in the pit. If sandy soil was added, the "humus" is sandy like. If clay like soil is added, the "humus" tends to be more clay like. Grey soils lead to a darker grey coloured "humus" and red or yellowish soils form into a darker red or yellow coloured "humus." Only when the added soil is crumbly and humus like or when vegetable matter like leaves are added in quantity does the final product really look or feel like crumbly humus. And that is what should be aimed for. However, whatever the soil looks like, the nutrient levels are considerably enhanced, as we have seen in the previous chapter.

The same applies to the humus formed from combining faeces alone with other ingredients, as is the case with humus formation in urine diverting systems like the "***Skyloo***" – see later chapter. If it is just a straight mix of faeces and poor soil, the soil will be greatly improved in terms of nutrient levels, but the texture will be improved to a much lesser extent. But this will depend on what ingredients have been added to the excreta. Thus if poor sandy soil is added to the bucket together with faeces and this combination is transferred together with paper into the jar composter, with more poor sandy soil added, the end result will be a material which is sandy in texture, but which has greatly improved nutrients levels. Its texture will be marginally improved. But a far better humus, both in terms of texture and nutrient levels, will be formed if the faeces are combined with a good topsoil, wood ash and vegetable matter as well - leaves are ideal. So what is formed in the pit or compost jar is much dependent on the ingredients – much like making a cake!

What ever the case, the overall aim of ecological sanitation is to utilise the nutrients available in processed human excreta and put it to the best possible use and thus enhance the production of food, especially vegetables, without the use of any external commercial fertiliser. Thus it pays in the end to add the best possible ingredients to the pit, if they are available. Humus like soil assists root growth and the overall growth of plants as well as improving the water retaining properties of the soil. It should be remembered that the growth of plants is not reliant solely on the presence of nutrients in the soil alone, but also on other factors which include the physical properties of the soil itself. A good soil texture is very important and this means plenty of humus. Plants grow better where the soil is fertile, crumbly and has a high content of living organisms - from bacteria and fungi to the small soil animals like worms and insects. Plants also require regular watering and sunlight. Adding a protective layer over the soil, like a mulch, also helps especially in areas of hot sun to retain water in the soil which would otherwise be lost in evaporation from the soils surface. The products formed from ecological toilets should be introduced into agriculture with these requirements in mind.

Excavating the *Fossa alterna* compost

This compost is best excavated from the ***Fossa alterna*** with a pick and shovel. It is best placed in bags at this stage and stored for later use. The mixing and aeration associated with "bagging" helps further the composting process. Leaves and extra soil can also be added. Alternatively it can be dug directly into beds or mixed with topsoil and then introduced into beds or containers. If there is any doubt about its safety it should be bagged and later combined with topsoil. If the mix in the pit has not been ideal, in other words if too little soil has been added to the pit, the pit soil may be tainted with an odour, and in this case it should be bagged and left for another six months. However if the right mix of ingredients has been added to the pit, the compost will be safe and pleasant to handle and should have a pleasant aroma. The excavated pit soil can also be laid in the sun, allowed to partly dry out, sieved or broken up, and then mixed with topsoil before application to vegetable gardens. The sieving is useful as it removes unwanted items such as plastic, rags and stones which may have fallen into the pit. After one year of composting the original characteristics of the excreta like odour, colour and texture will have changed completely. The compost smells good and is pleasant to handle. If the second pit of the ***Fossa alterna*** has been used for composting, or for making leaf mould, as is recommended in the first year, this material will also be very valuable in the garden. The main use will be for vegetable growing.

Compost being excavated from a *Fossa alterna* pit at the Friend Foundation, Harare (left) and in Niassa Province, Mozambique (right), a project of WaterAid. It is best placed in bags for storage first, and then mixed with topsoil and applied to vegetable gardens or containers. It can also be mixed with topsoil.

Volumes of compost formed

It must be accepted that the total volume of compost formed every year in a family owned eco-latrine, like a ***Fossa alterna***, is relatively small - around 500 - 600 litres. Thus compost derived from these toilet systems is not sufficient to apply generally to the fields to obtain any noticeable widespread effect. However the effect can be pronounced if the compost is applied to the small backyard vegetable garden and various means must be sought to make the most effective use of this precious product.

Vegetables can be planted directly into the ***Fossa alterna*** compost, but this is an uneconomical method of using the material. The richness of the compost allows for mixing with poor unfertile soils. Thus the mixing of ***Fossa compost*** with topsoil is the recommended method. The most practical method is to apply and mix the ***Fossa alterna*** soil with soil already present on a vegetable bed or to prepare a new bed using the ***Fossa alterna*** soil mixed with local topsoil. Importing leave

compost and normal compost obviously will also help a great deal in the formation of a new vegetable bed if it is available.
In fact a poor infertile soil in which plants can hardly grow can be transformed into a valuable planting soil, simply by mixing in ***Fossa*** compost with the local topsoil. The volume may be almost trebled if one part of eco-humus to two parts topsoil or mixed with one part natural soil and one part of leaf mould. Thus a 1.5 cu.m. soil/pit compost mix may result from a year of use of the eco-latrine if a 1:2 mix is used. It is good to mix a variety of composts from different sources into the topsoil to enhance its value as a fertile environment for plants.

Thus the various possible soil combinations are as follows:
1. Neat humus (eco-humus) from ***Fossa alterna.*** **(500 litres)**
2. Mix of eco-humus and natural topsoil (ratio 50/50%). **(1000 litres)**
3. Mix of eco-humus/natural topsoil (ratio 33% and 66%). **(1500 litres)**
4. Mix of eco-humus/natural topsoil and leaf compost (33/33/33%). **(1500 litres)**
5. Mix of eco-humus/natural topsoil, leaf mould and compost. (25/25/25/25%). **(2000 litres)**

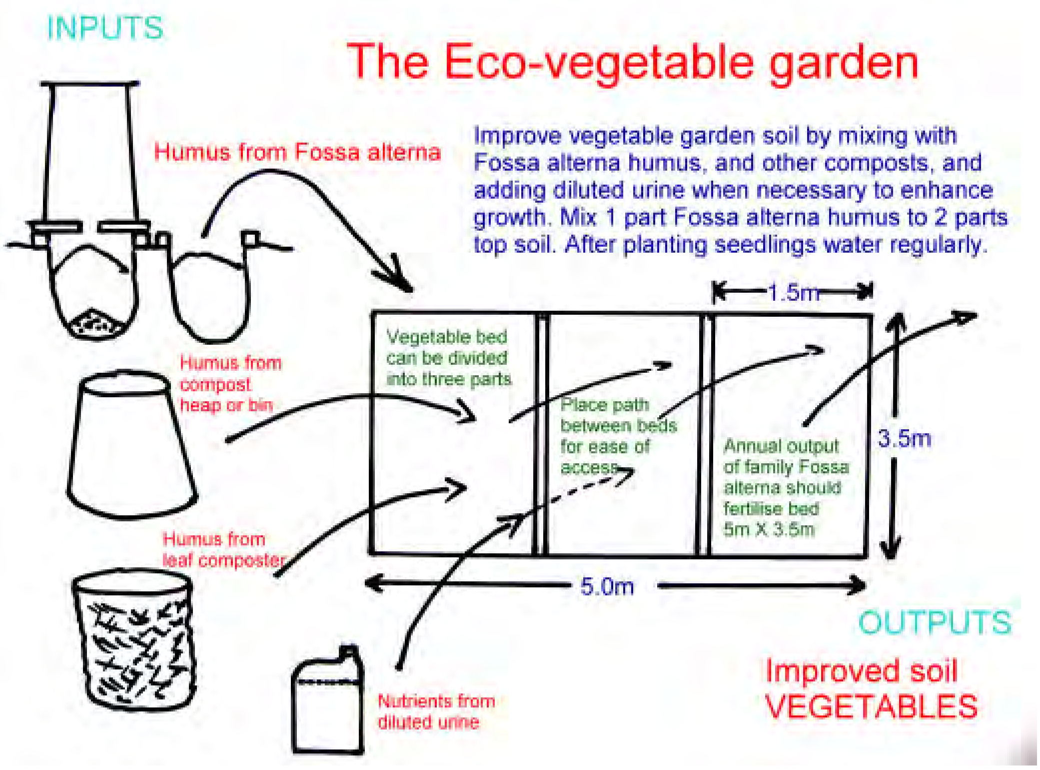
Handling the compost and safety
The compost derived from ***Fossa alterna*** pits should be relatively safe to handle (as discussed in the previous chapter and also the chapter on Health) if processed correctly with adequate amounts of additional materials being added to the pit and 12 month period of composting being allowed. There will be variations in the quality of the compost depending on the ingredients in the pit. The more soil and leaves are added, the more effective will be the composting process, and the better the final product will be. The ratio of excreta to additional materials should be about 50:50. As with all gardening practice, hands should be washed after handling compost and always before eating food. If simple hygiene principles are followed there should be little danger involved with handling compost. Every effort should be made to teach children not to eat soil, But children will be children! Children all over the world have a habit of eating nasty things. If there is any doubt about the compost from a health point of view it is best to transfer it into sacks for further storage for a further period of 6 months. Alternatively transfer to another pit, cover with soil and plant a tree. When this extra composting or transfer takes place it is possible also to add leaves, which helps make the final product darker and more crumbly. Its water retaining properties can then be enhanced.

HAND WASHING IS ESSENTIAL

The various methods of using toilet compost in the garden

We now combine the use of the eco-toilet and the vegetable garden so they can operate with one common aim – to provide more food for the family.

We now describe practical ways of using the toilet compost and other valuable composts and urine to provide more food for the family. To get the most effective production from a small vegetable garden it is wise to take advantage of all these various products if they are available. The small vegetable garden is built to use the materials derived from the toilet with toilet compost being added every year to restore what nutrients the plants have withdrawn. The vegetable garden is linked not only to the toilet, but also to the compost heap, the leaf composting basket and to any source of urine the family can produce. The aim is to bring all these parts of organic gardening together – compost, eco-humus, urine, for the best production of vegetables. Growing vegetables in small containers is also a practical method, especially where space is limited. Buckets or cement basins are ideal.



Application of pit compost.

Pit compost can be mixed with the existing topsoil soil at the rate of 2 parts topsoil to 1 part pit compost. Using the size of one bed illustrated above (3.5m X 1.5m) the toilet compost is applied to each of the three beds by distributing 12 piles, each of 15 litres over the bed with 0.5m between each pile. Thus 12 piles of 15 litres each can be made over each 3.5 X 1.5m bed. That is a total of 12 X 15 litres = 180 litres. This is about 35 litres humus per square metre of bed. The total annual production of humus from a family (0.5-0.6cu.m.) should be sufficient to distribute over 3 such beds totalling about 15sq.m. Once deposited in a measured way from the buckets, the humus is spread out over the surface with a hoe (badza) and then dug in and thoroughly mixed with the local soil to a depth of about 10cm.

1. Preparing and managing an eco-garden linked to the *Fossa alterna*

In this case a special small vegetable garden was prepared near to the toilet to use the yearly supply of ***Fossa alterna*** compost. The photos and captions describe the process.


Preparing the bed of the eco-vegetable garden. In this case an old vegetable bed is being prepared by weeding, digging down and mixing the soil over an area of approximately 15 sq.m. The vegetable garden was divided into three beds, each of about 5 sq.m. each. In the background on the left photo the humus from the *Fossa alterna* is being dug out. On the right two heaps of *Fossa alterna* humus have been excavated. The 360 litres of humus was divided into two piles of 180 litres each. This volume of humus was sufficient to enrich two of the three beds in this vegetable garden.


Three beds were prepared each 1.5m X 3.5m in area (5.25 sq.m.). The eco-humus was mixed with the existing soil in two of the beds and the same amount of local red topsoil was mixed in the central bed (for comparisons). The humus was applied to each bed by distributing 12 piles, each of 15 litres over the bed with 0.5m between each pile. Thus 12 piles were made over each bed (12 X 15 litres = 180 litres). The humus was spread out over the surface with a hoe (badza) and then dug in and mixed with the local soil to a depth of about 10cm.


This was then spread out over the surface as evenly as possible with a rake. This application rate is thus 180 litres humus to 5.25 sq.m. of bed (35 litres per square metre. If we calculate that the depth of the improved soil is 10cm, the total volume of the mix is 100 litres per sq. m. To make up with 100 litres about 35 litres humus has been mixed with 65 litres topsoil. That is a ratio 2 topsoil (65 litres) to 1 humus (35

litres). A ratio of 2:1. After watering, the seedlings are planted. In this case spinach and rape. 50 plants were sown in each of three beds making a total of 150 plants.


An example of the eco-vegetable garden just planted with seedlings with the *Fossa alterna* toilet behind. A family should provide enough excreta, when combined and composted with soil, leaves and wood ash to make 0.5 – 0.6 cu.m. eco-humus per year. This is enough to apply to an eco-garden 3.5m X 5m.


After 4 weeks a good harvest of green vegetables has grown ready for the first cropping. In the bed mixed with extra *Fossa alterna* soil, the spinach harvest was increased by 1.7 times, and rape 1.4 times, despite the existing bed being already quite adequate in terms of soil nutrients. After 6 weeks and two croppings the increase had been reduced slightly to1.6 times (spinach) and 1.3 times (rape). After 8 weeks and three croppings the total weight of spinach cropped on Bed A was 4754 gms, compared to 3027 gms on Bed B. After 8 weeks and three croppings the total weight of rape cropped on Bed A was 3233 gms, compared to 2736 gms on Bed B . Thus overall the application of the humus increased the spinach crop by 1.57 times and the rape crop by 1.18 times. Additional output of green vegetables can be achieved by the regular application of diluted urine. This is described later in this book.


The first crop of spinach and rape being harvested at 4 weeks. The vegetables in this case were prepared for sale in neat bundles. Further crops can be harvested. When the crops are finished, the old plants are removed and the soil dug down and aerated. Additional compost can be added if required. New seedlings are then planted. The vegetable garden is maintained in the same way as any other vegetable garden. Regular weeding and watering is essential to obtain maximum crop output.

2. Digging *Fossa alterna* compost into existing vegetable gardens and planting maize seed in plugs of *Fossa alterna* compost in the maize field.

The most obvious and simplest method is just to dig in the humus into existing vegetable beds, turning and mixing the new humus into the layer of topsoil already present. If this is done carefully the new topsoil may be enhanced over an area of about 10 square metres of bed with0.5 cu.m. humus. With less care the humus may be distributed unevenly. When a very poor soil is mixed with a good soil or eco-humus, the resulting mixture will be patchy unless the mixing has been done well. Some plants may appear to grow well and others not. So thorough mixing is very important.


The *Fossa alterna* of Mr and Mrs Nyirenda of Yazoza Village, Embangweni, Malawi. The soil is hard and there was no need for a pit lining. The humus had recently been dug out of the pit (right).


Mrs Nyirenda applies the humus from the Fossa alterna pit to the soil in her vegetable garden. The material is first applied with a shovel over the surface. It is then spread out and dug in and mixed with the soil with a hoe. Planting begins with the advent of the rains.

Planting maize seed


In poor soil the germination of maize seed may be helped by planting in plugs of richer soil like *Fossa alterna* compost. This technique may give the young plants a better start. Treatment with urine and water greatly assists the further growth of maize as described later in this book.

3. Growing tomatoes in compost derived from the urine diverting toilet.

When the urine diverting toilet is used urine builds up in the urine chamber and compost builds up in the secondary composting unit. This compost is a mix of faeces, soil, ash and leaves. This final compost is rich in nutrients and also contains seeds which have passed through the alimentary canal. If this compost is placed in a container and watered young tomato plants will spontaneously grow. These may germinate in considerable numbers, but if most of the young plants are removed leaving the strongest two, the tomatoes will grow strongly using the nutrients contained in the bucket.

Compost from the urine diverting toilet is placed in a bucket and watered. Tomato seedlings grow spontaneously. All weaker plants are removed leaving the strongest one or two. These grow on the nutrients available in the bucket. Extra nutrients like dilute urine can be applied if necessary.

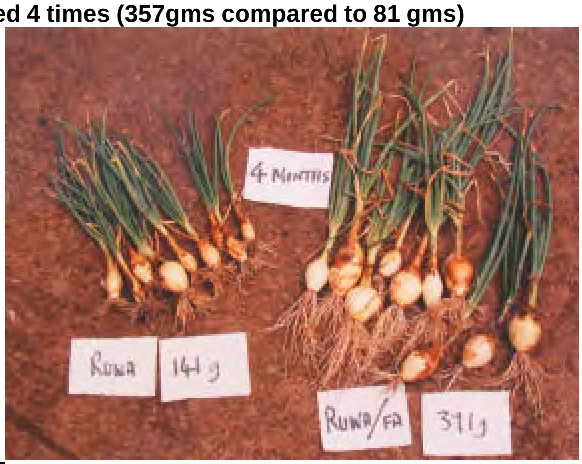
Growing tomatoes from compost derived from urine diverting toilets is a very good method of demonstrating the "closing the loop" concept. The nutrients and seeds coming out of the system are put back into the system and recycled.

4. Effect of enhancing poor topsoil with pit compost in containers

Most soils in this part of Africa are very deficient in nutrients and unless fertilised in some way, produce very poor yields. The fertility of poor soils can be increased significantly by adding compost and also cow manure, and these methods are often practiced and should be encouraged more. However, cow manure may not always be available, especially where people live in the peri-urban fringes. On this page you can see the effect of enhancing very poor soil (taken from Epworth) with pit compost (taken from ***Fossa alterna)***. In each case shown, the very poor topsoil was mixed with an equal volume of pit compost (5 litres + 5 litres). The increase in growth is very significant. Poor soils, such as those used in the trial are very common in Africa. By combining poor soil and eco-humus, vegetable production can be enhanced significantly. Output of onion and leafy vegetables can be increased further by applying diluted urine in addition to eco-humus.

Left Photo: The photo shows spinach grown on poor soil (from Epworth) in left bucket compared to spinach grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 30 days of growth. The harvest was increased 7 times (546 gms compared to 72 gms).

Right Photo: The photo shows covo grown on poor soil (from Epworth) in the left bucket compared to covo grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 30 days of growth. The harvest was increased 4 times (357gms compared to 81 gms)



Left Photo: The photo shows lettuce grown on poor soil (from Epworth) in left bucket compared to lettuce grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 30 days of growth. The harvest was increased 7 times (912 gms compared to 122 gms).

Right Photo: The photo shows onion grown on poor soil (from Epworth) in the left bucket compared to onion grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 4 months of growth. The harvest was increased nearly 3 times (391gms compared to 141gms). Whilst this a significant increase in onion production, the best crops are produced on very rich organic soil. Onions are hungry feeders. See next chapter on use of urine.

5. Further methods of growing vegetables in containers

Other methods of utilising the relatively small quantities of humus available annually from eco-latrines include growing vegetables in containers like plastic buckets, old car tyres, basins and jars and even plastic bags. Here smaller quantities of humus can be more efficiently mixed and used in a small garden or small vegetable plot where the soil is poor. Such containers can be filled with a mix of eco-humus and topsoil or with eco-humus, topsoil and leaf litter or compost. In the small back yard, this may be an ideal method of producing vegetables. The method of using car tyres and buckets has also been used in Mexico and elsewhere (Paco Arroyo, pers. comm).

Growing vegetables in plastic bags

Plastic bags are perhaps the cheapest method of containing the soil in which vegetables can grow. The life of the bag will generally be a single season, especially if the bags are exposed to the sun. Small holes are punched into the lower side of the bag for drainage.

Growing tomatoes in bags

Growing vegetables in plastic buckets

Plastic buckets are ideal for growing many vegetables and a variety of crops including tomato, onion, rape, spinach and even maize can successfully be grown in them. 10 litre, 15 litre and 20 litre plastic buckets can be used to grow vegetables. A series of about 5 X 8mm diameter holes are drilled in the base for drainage. Plastic buckets have the advantage that they are light and have handles and are portable, so can be taken into and out of the sun where necessary. They can be placed in any suitable parts of the garden or yard. Once the plants have been reaped the soil in the buckets can easily be tipped out and reconstituted with other compost or soils and placed back in the bucket for a new planting. Any roots that have congested the bucket can be removed by sieving. Also because of their shape they tend to conserve water quite well. Plastic buckets, when looked after can have several years of life. The same combinations of eco-humus and soil and leaf mould can be used in the buckets as has been described above. Applying mulch also helps.

Ten litre buckets can be used to grow a range of vegetables. They are light and durable. Here rape are being grown in the left and green pepper on the right. A series of drainage holes are drilled in the base.

Growing vegetables in concrete containers

The most economical method of making containers that will last year after year and be recharged many times is to use off-the-shelf plastic buckets or basins as a mould and caste replicates in concrete. The concrete containers are heavier than the plastic bucket or basin, and thus more cumbersome to move, but in the long term they are very durable. However they are not resistant to being dropped. Split cement jars can be made of 30 or 80 litre capacity and a good concrete basin of 10 litres capacity. The best shape for growing shallow rooted vegetables (onion, lettuce, rape, covo, spinach etc) is broader and not so deep, so the concrete basin of 10 litres capacity (38cm in diameter and 14cm deep) is possibly best and most economical. Deeper rooted vegetables like maize will prefer 10 - 20 litre buckets as soil containers, although, they too will grow in cement basins (see later). Up to 50 ten litre concrete basins can be moulded from a single 50 kg bag of cement and river sand. Each basin will contain up to 3 - 5 rape, covo, lettuce or spinach plants, two tomatoes or up to 10+ onion plants.

It means that by making 50 concrete basins from a single bag of cement there is the potential to grow about 250 - 500 onions, or 150 - 250 rape, covo or spinach plants. Even maize and tomato plants can be grown in these containers (see later). Thus this is quite an effective way of growing vegetables if space is limited. With a good soil up to 2 kg spinach, 1 kg rape, 0.5 kg green pepper and 1.4 kg of onion, can be grown in a 10 litre container. However the amount of the crop depends on the soil fertility, the amount of watering and sunlight and the amount of liquid feed added - there is much variation.

The basins when filled with soil have a larger surface area exposed to the atmosphere compared to the standard 10 litre plastic bucket. This means that a few more vegetables can be planted in the increased area. But the evaporative surface is increased. The basins will therefore require more frequent watering and a good mulch of leaves helps to retain water, reduces weeds and reduces sun damage on the soil surface. It is therefore wise to include more humus in the soil mix to improve the water retaining properties of the soil mix and also to add a mulch of leaves on the surface. The method of making these containers is described in the chapter on special construction techniques.

Since the volume of the soil, both in shallow vegetable gardens and containers, is not great, there is a tendency for the water contained in the soil to be reduced more readily by evaporation or transpiration. Thus more frequent watering is required. As plants become larger and their leaf area increases, they will transpire a lot of water, which will need replacing in the soil. Thus larger plants growing on containers will need frequent watering in hot dry weather. This can be partly compensated by the inclusion of humus in the soil mix and by mulching, but large leafy plants do use much water in transpiration which must be replaced in the soil to avoid wilting.

Fine crop of covo growing in 10 litre cement basins. With care 50 of these basins can be made from one 50 kg bag of cement and river sand. The covo are grown from seed. The soil mix in this case is half leaf mould and half composted kitchen and animal manure. The plants are also fed a liquid feed of water and urine mixed at a 3:1 ratio, 0.5 litres per basin, twice a week. The plants are watered at all other times with either borehole water or grey water from the house. Grey water derived from shower and basin.

2 kg spinach can be grown in a single 10 litre cement basin and up to 12 onions weighing 1.4 kg.

Also limited amounts of soil contain only finite quantities of nutrient. There will come a time when the nutrients available in the container or bucket will be used up (unless this is replaced by liquid feeds) and this will have an effect on plant growth and yield. However as we shall see in the next chapter, ***Fossa alterna*** soil mixed with poor soil in a container can produce an excellent crop of vegetables during the growing season and far more than the poor soil alone. But the nutrients available cannot last for ever. Normally a charge of humus and topsoil will provide enough nutrients for a single crop and then soil enhancement will be required again, either by remixing with further humus or by nutrient enhancement with liquid feeds or compost etc.

Also where poor natural soils are mixed with eco-humus there will normally be fewer weeds developing in the bed, which means that more of the nutrients released from the soil combination will go into vegetable growth. Where garden compost is used to grow vegetables it is normally linked to the rapid growth of weeds which must be removed if the nutrients in the soil are to be fully utilised by the food product. Mulch can help to reduce weeds and therefore increase the proportion of nutrients taken by the productive vegetables compared to the unproductive weeds.

Where eco-humus is mixed with very poor soil, particularly sandy soil the value of the eco-humus comes under the maximum test, as shown in the trials described in the next chapter. The resulting combination will have much reduced nutrient levels compared to the levels found in the eco-humus itself. If the eco-humus itself is derived from a combination of excreta and poor soil alone, the nutrient levels may only reach marginal levels for some vegetables. Mineral deficiencies can be detected in certain plants like rape. A purple colouration of the leaves may result when the phosphorus levels are low and a yellowing of the leaf fringes denotes reduced levels of magnesium. Pale green leaves denote low levels of nitrogen.

Additional requirement for nutrients

The final output of crops grown on a mix of ***Fossa alterna*** humus and topsoil can be enhanced further by applying an organic liquid plant food or a mix of urine and water to the soil. Most soils used in gardening are enhanced by the addition of additional nutrients in the form of manure, compost, organic liquid plant foods or inorganic fertilisers. In fact it would be normal practice to add liquid feed or manure or compost to a vegetable garden to produce optimal growth of vegetables. The nutrients used up by the plants in their growth must be restored to the soil. Inorganic fertilisers are widely used in agriculture, but these will be little used in the organic farming concepts promoted by eco-san, although a careful mix of inorganic and organic methods is acceptable. Thus if the mix of eco-humus and local topsoil shows signs of becoming depleted, as indicated by signs on the plants, like paling leaf colour, then it is perfectly acceptable, and even desirable to add a liquid feed - and the liquid feed most suitable in eco-san is urine diluted with water. Young plants need plenty of phosphorus to help establish their root system and to establish early shoot development. This is where the well balanced distribution of nutrients in ***Fossa alterna*** humus helps a great deal. With its high content of nitrogen and much lower content of phosphorus, the urine/water mix is best applied when the plants are established to gain extra crop yield. Too much nitrogen at an early stage, as applied with urine, may not help the early formation of the plant. Urine application must come later.

A variety of vegetables growing in buckets - from the front: covo, then lettuce and spinach further back. The two rows on the left hand side are growing in poor local top soils and on the right hand side are growing in a 50/50 mix of poor local top soils and *Fossa alterna* compost. A significant increase in growth can be seen in those vegetables where the poor top soil (taken from Epworth and Ruwa) is enhanced with *Fossa alterna* compost.

6. Growing trees in toilet compost

When an *Arborloo* is used the tree is planted directly in the toilet pit. But it is also possible to plant trees in toilet compost which has been excavated from a compost toilet pit and transferred to a hole dug specifically for a tree. The following photos were taken when pit compost was excavated from a *Fossa alterna* pit after only 6 months of processing, when it was not fully composted (12 months is recommended). The material was sufficiently composted however to be easily transferred from the toilet pit to the tree pit.


A tree pit is dug 60cmX60cmX60cm deep. Toilet compost is dug out.


The tree pit is filled with the toilet compost to ground level. A circle of bricks is laid around the tree pit and filled again with good topsoil.


A hole is dug in the middle of the bed and topsoil added to the base of the hole. A young tree is planted in the hole (Mulberry), and the soil levelled. Leaf mulch is then added and the tree watered. The final picture in the series shows the mulberry tree 4 months after planting. Vigorous new growth of leaves and even fruit can be seen, the signs of a healthy young plant. All work undertaken by writer!

7. Using pit compost in the flower bed

Pit compost can also be used to enhance all soils including those used for ornamental purposes in flower beds. This may be the preferred methods if there is some resistance at first to applying the humus on to vegetable beds. The same technique is used as on the vegetable beds. Humus from the toilet, once well composted can be applied with a bucket to the soil, at the rate of about 35 litres humus per square metre soil. Humus can be held in sacks before application, and this tends to improve the quality and safety of the product, since it involves aeration, turning and greater storage. The new humus is spread out and then mixed in with the existing topsoil, making a new soil which is more organic and fertile. Seedling flowers can then be sown and the resulting colour will be a great pleasure for the householder. Once established, urine can also be applied to the beds by mixing with water (10:1) and apply weekly in a watering can. Nutrients derived from human excreta can assist in the growth of all plants – and that includes flowers and other decorative ornamentals.

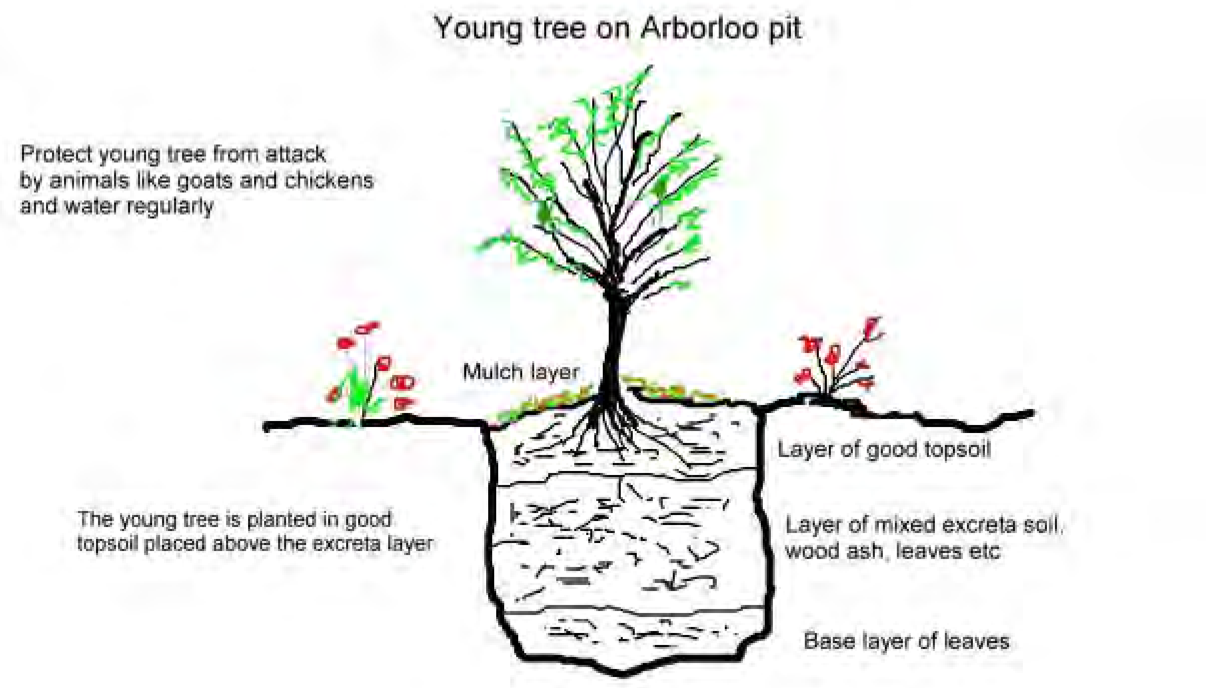

The *Fossa alterna* humus is carried to the bed in buckets and spaced so that about 3 to 4 ten litre buckets of humus covers a square metre of bed area. The piles are then spread out and mixed with the existing topsoil with a hoe.


The Dutch hoe is a fine gardening tool and valuable for many jobs of the vegetable or flower bed. Here it is used to mix the new humus with topsoil.

The new bed with enhanced growth of flowers

12. Growing trees on composted toilet pits

After a period which can vary from a few months to a few years, depending on the pit size and extent of use, the compost pit will be filled with a composting mix of ingredients. In the case of the ***Arborloo***, it is time to move the structure, including the concrete slab and any ring beam to a new site. The toilet itself moves on a "never ending" journey, through the "lands." A new site will have been chosen and possibly a pit dug, but it is always wise to place the ring beam first and then dig the pit within the ring beam. This makes a much more stable unit.



Preparations for tree planting

The contents of the used pit (filled with excreta, soil/ash/leaves etc) are now levelled off and topped up with a generous layer of leaves followed by fertile soil, at least 150mm deep. This soil can come from old compost heaps, fertile soil/leaf litter found under trees or any other place where the soil looks good. The aim is to plant the young tree in topsoil so the roots are placed well above the composting excreta layer below.

What is important with the ***Arborloo*** is that a generous layer of soil (15cm) is laid over the excreta/soil layer in which the young tree is planted. If a good layer of leaves followed by top-soil is added to the excreta in the pit, the young tree can be added the same day as topping up with soil. But there is no reason to delay the movement of the latrine if no trees are available for planting. The latrine can be moved and the pit topped up with soil awaiting the arrival of a new young tree. In fact some may prefer this method, as it gives time for the excreta in the pit to partly convert into humus before the tree is planted. More topsoil can then be added before planting. If water is scarce, it is actually advisable to delay tree planting until the rains begin. Then the chances of the young tree dying as a result of a lack of water will be much less. Young trees need a lot of care, protection and water.


Left: Women from the Sanitation club in Epwengeni Village, Embangweni, Malawi, perform a play showing how trees are planted in *Arborloo pits.* The Village has large numbers of *Arborloos* in operation. Right: Young fruit tree being planted by children in Embangweni, Malawi. Right photo: Jim McGill.

Planting young trees

Young trees can be obtained from a nursery, or in some cases can be taken from cuttings from existing trees (mulberry, banana) or can be grown from seeds (guava, paw paw, mango, avocado etc). This is described in the chapter on gardening techniques. Mulberry, banana, gum, mango, guava, paw paw & avocado do well. In fact most trees will thrive if given the right opportunity. Citrus trees can also be grown, but need more care. Experiments in Harare have shown that when planted in a good layer of topsoil covering very organic pits, most trees will thrive, including a wide range of fruit trees, indigenous trees, ornamental trees and trees used for construction or fuel. At least three things are important for young trees.

1. Keep the young tree roots well away from the excreta layer.
2. Protect the young tree from goats, chickens etc with a protective basket
3. Water regularly. A mulch of leaves or grass helps to retain water in the soil.


Left: Right: In a programme in Kusa Village on the shores of Lake Victoria, Kenya, many young trees have been planted on *Arborloo* pits. This young citrus tree is being planted in the soil placed above the pit contents. Thanks to RELMA. Right: This *Arborloo* at the Eco-Ed Trust has just been moved onto a new site (rear right). The old pit has been topped up with soil, a tree planted and mulch added. Note substantial protection against animals. Thanks to Jim and Jill Latham, Eco-Ed Trust.

The growing roots of the young tree first invade the topsoil layer, whilst the excreta below is turning into humus. So the young tree does not immediately gain benefit from the formation of humus derived from human excreta. This benefit will be realised later on. Because of the highly rich nature of the pit contents, there may be invasions of the pit by roots already present in the soil. If the young tree for any reason begins to struggle, a new tree can be planted later. Also if the trees are very young it may better to allow them to establish themselves in buckets, pots or larger containers first, so the root system can grow more extensively and become more resilient before transplanting into the pit. Experimentation will be required. There will be a variation in local conditions - soils, climate, season etc. The most suitable tree type will vary with the area and altitude. Also the owner will choose some trees in preference to others. Some may choose trees for fruit, others for fuel, others for shade etc. The banana is perhaps the most widely grown fruit tree on traditional latrine pits. But the orange and tangerine are the most popular in more recent ***Arborloo*** programmes.

In some cases the tree may not grow fast at first, a condition known as “hesitancy.” Obviously a pit full of richly organic material may not be the most ideal environment in which young trees can grow. But with time, the conditions of the pit become favourable. Some trees are more tolerant of the richly organic conditions than others. Mulberry is a very good tree species to start. It makes tasty fruit and is very tolerant of the rich pit environment. It can also be grown from cuttings.

Looking after young trees

There are some trees which may fail to grow on the first attempt for various reasons. Sometimes these will have been attacked by goats or chickens or dug out or trodden on by children, or simply not watered. Sometimes a poor soil will have been chosen to cover the excreta layer or the soil layer may have been too thin (trees will die if placed in or very close to raw excreta!). And some trees are hardier than others. So some tree deaths can be expected. Try again with a new tree - replanting is the order of the day!

Common gardening practice must be applied to the planting of young trees. The soil should be fertile (that is the layer of soil placed on top of the excreta). The young tree should be healthy, protected against animals, children, possibly excess sun and it must be watered regularly. The soil should ideally be covered with a layer of mulch. Mulch is a very valuable addition to the topsoil. It is a layer of material, preferably organic material that is placed on the soil surface around the tree. It is a protector of the topsoil. The layer of mulch helps to conserve moisture in the soil and thus reduces the amount of water required. It holds down weeds and also protects the soil from the effects of sun and wind. The layer of mulch improves the soil structure and fertility. It can be made of leaves, leaf compost, grass cuttings, compost or other decomposing vegetable matter. Some animal manure, compost, etc or other suitable fertiliser might even be dug into the topsoil to assist the young plant once established. Here the local forestry or nursery people will know what to do. The aim is to help the tree to get established and stabilised in the layer of topsoil, in preparation for its penetration into the decomposing layer.

Hesitancy

For various reasons a young tree may hesitate to grow with maximum vigour at first. It may be stressed for a number of reasons and that is why every effort must be made to encourage the young tree in its first months after transplanting. If all other factors in the topsoil are ideal, the tree should have a good start. But if the organic layer is too close to the roots the plant may hesitate or even die. The tree roots are actually quite sensitive to the soil beneath and the plant as a whole may wait until it senses the best time to start growing more rapidly. That is when the excreta is fully converted into a humus which can be tolerated by the roots. There is a balance between the rate of conversion from excreta to humus and the rate of growth of the roots into the deeper layers. One thing is certain, when the time is right, the young tree will certainly begin to grow vigorously.

Replanting

If for any one of a number of reasons the young tree does not grow, it should be replaced. If the plant struggles for a period of 3 - 4 months then it is best to take the tree out and replant with a new tree. It may be wise to take out the composted soil from the pit, loosen and mix up and reapply to the pit and replant the same tree or preferably a new tree and water etc. Some trees are stronger and more tolerant than others, even when they come from a nursery. Some people who dig out the tree pit prefer to use the humus on their vegetables. That choice is of course optional. Many people may decide the humus is more important on vegetables. But opinions vary greatly.

Feeding the trees

All trees require a good supply of nutrients if they are to grow well. This is particularly true for fruit trees which are planted to produce fruit. The amount of fruit produced will eventually depend on how much nutrient the tree can gain from the soil. The early growth of trees can certainly be sustained from the nutrients held in the composted pit soil. But during heavy rain, part of the nitrogen will be lost from the topsoil, although phosphorus is normally held in place far better by the soil. Also trees use up much of the nutrients held in the soil and their root systems search wider and wider for a supply of food. So for the best results, particularly with fruit trees, extra feeding will be required.

Each type of tree has its own very specific requirements for feeding. Avocado pears, for instance, require more phosphate and potash and very little nitrogen. Banana trees require large amounts of nitrogen and potash. Citrus trees require more of a balanced diet. When fed with compound fertilisers, fruit trees require between 250 – 500gms of fertiliser per year for each year of life if they are to produce good yields. This is normally given in 2 or 3 doses over the year. However, all trees require the most phosphorus at an early stage of root growth and shoot formation. Then they require more nitrogen for vegetative growth. But the final stage is critical. The trees require generous amounts of potassium to produce fruit in abundance.

It is wise to dig in compost or manure around the tree from time to time. For most trees, about 10 kg manure or compost (a wheel barrow full) will be required each year for the first two years. The amount required increases by about 5kg for every successive year, so apply about 15kg in year 3, 20 kg in year 4, 25 kg in year 6 and so on. In eco-san, one option for feeding will be diluted urine. Since urine contains a lot of nitrogen and much less potassium, it is wise to dilute the urine first, and then add a source of potassium. The source of potassium most commonly available is wood ash. As a rule of thumb, most trees, once they have been growing for two years, respond well to a monthly application of a mix of 2 litres urine to 10 litres water (5:1) to which has been added a mug full of dry wood ash and well stirred. This can be applied with a watering can. Several charges of this mix can be added to more mature trees, especially during the rainy season. It helps if the soil around the tree is well mulched.

Some examples of growing young trees from cuttings and seed

Many of the most successful fruit trees for planting on ***Arborloo*** pits can be grown easily from seed or cuttings. These include banana, mulberry, guava, paw paw, avocado pear, mango and many others. If a nursery is not available for a supply of young trees it is best to use trees which are easy to propagate from cuttings or seed in the home garden. Citrus trees are more difficult to grow from seed and will normally be purchased as grafted trees from a nursery. Innovative programmes which promote the ***Arborloo*** method may also provide not only small material subsidies like divided packets of cement to make a concrete slab, but also tree seeds and/or seedlings. Instructions for toilet construction and use and the planting and caring of trees can also be included in such packages, sometimes called “start up kits.” The young tree or tree seeds can be planted in a suitable container, in preparation for later transplanting, at the same time as the concrete slab is made and the ***Arborloo*** is built and put to use. This period may extend between 6 and 12 months. By that time the young tree will have become well established in the container and will be ready for transfer to the ***Arborloo*** pit. It is a good way of starting off the process of uniting sanitation with food production.

Mulberry – a good example.

Perhaps the most successful tree to grow from cuttings is the mulberry. This is an excellent tree to start because it rarely fails and grows particularly well on organic pits. It also provides delicious fruit, rich in iron and vitamins A, B and C. There are two types of mulberry, black (*Morus nigra*) and white (*Morus alba*). The black type is the best known and the most tasty.

The method involves cutting a piece of **mulberry** tree branch about the size and width of a pencil. Each cutting should have 4 or 5 good buds on it. Cut at an angle with a shark knife or cutter. Remove any leaves and plant in potting soil or humus in a pot. Plant so the part nearest to main stem of the cutting is placed in the soil. Keep well watered. After a few weeks new shoots will appear on the cuttings. The young tree can be transferred into a bigger container to allow the roots to extend prior to planting on the ***Arborloo*** pit. This tree is usefully used in Compost toilet starter kits, as it is easy to propagate in large numbers.

Young mulberry sprouting new leaves 3 weeks after planting the cutting. Once well established, the young tree can be transplanted into a larger container or bag prior to the final transplant into the *Arborloo* pit. (Photo: April 2004). Middle photo - the tree is growing fast in a 10 litre bucket. Right the tree has been planted and after less than a year the mulberry is growing fast. The tree on the right is also being fed with a urine-water mix once a week (2 litres urine + 10 litres water). Trees grow particularly well during the rainy period, when the temperature is also high in Southern Africa. The start of the rains (November/December) is a good time to plant trees in organic or *Arborloo* pits.

Guava

Guava (*Psidium guajava*) is a tasty, nutritious and prolific fruit bearer and is very hardy. It grows almost like a weed in most parts of Southern Africa once established. Very often young trees will germinate and grow in areas where guava has been eaten and the pith thrown to one side or has just fallen off the tree. Guava can also be grown from seed and this is a good way of distributing the trees in ***Arborloo*** programmes. But guava seeds do take a long time to germinate

Guava like mulberry and most of the other trees grown on ***Arborloo*** pits grow into very large trees eventually. The pit should be spaced about 4 - 6 metres apart. The young trees pick up the nutrients left in the mix of composted excreta, soil, ash and leaves. The presence of a good supply of phosphorus is particularly valuable when the tree is young. Also the presence of potassium is particularly valuable for later fruiting. As the tree matures, extra supplies of nutrients will be required and this can be provided by adding diluted urine mixed with wood ash (see ***Arborloo*** chapter). .

A pink fleshed cultivar which has been cut to reveal the seeds. In the region guava fruit ripens between February and April. The seeds should be taken from fresh fruit and soaked in water to remove the fruit pulp. The seeds are dried in the shade (right) and stored in a cool dry place for later planting. It is wise to plant 3 or 4 seeds in a suitable container or potting bag and later thin out the best young tree.

Once established the young guava tree can be transplanted into the *Arborloo* pit. On the right a young Guava growing in a potting bag. On the left a wild sown guava growing in a garden. Where guavas are common in the garden, large numbers of guava seeds become dispersed and grow like weeds. The guava is a tough resilient tree, with delicious fruit and like the mulberry a good choice for the *Arborloo* pit.

Avocado

Avocado (*Persea americana*) trees grow very large and provide huge amounts of fruit over the years. After eating the fruit take the large seed and plant in a clean deep container with the point of the fruit facing upwards and just beneath the surface of the potting soil. Keep well watered. Some people place the fruits in water and wait for them to germinate. Some seeds may be attacked by fungus which causes root rot and this can be dealt with by placing the seed in water at 50 degrees C for 30 minutes before placing in the soil. Root rot kills trees slowly and can spread to healthy trees. Once well established the young tree can be placed on the filled ***Arborloo*** pit. Since the trees can grow very large, the pits are best spaced between 8 and 10 metres apart.


Bucket of avocado seeds. On right a seed has germinated in a small container.


Avocadoes growing in bags from seed originally soaked in water and once germinated transferred to the soil in the bag. On the right more mature avocado growing on an organic pit at the Friend Foundation in Harare.

Other Trees

Many other trees can be grown from seed including paw paw and mango. The tree of choice is chosen by the family itself, bearing in mind that some trees are easier to grow than others. It is best to consult the local tree nursery or Forestry Department for all details of tree cultivation and care.

Photo gallery of trees growing on *Arborloo* or organic pits

Mr and Mrs Phiri and Mr Twitty Mukundia of CCAP in Embangweni inspect a paw paw planted on an *Arborloo* pit and well protected against animals. Several fruit trees are growing on a series of Arborloo pits in Chiputa Village, Embangweni. Thanks to WaterAid and CCAP.

Citrus trees (orange) growing on *Arborloo* pit in Kusa Village near Kisumu, Kenya (left photo). Note the banana in the background. Bananas flourish on old latrine pits and also *Arborloo* pits.

Trees are amongst Natures greatest wonders.

Trees grown on *Arborloo* pits at the Porta farm, Zimbabwe Project of Mvuramanzi Trust.

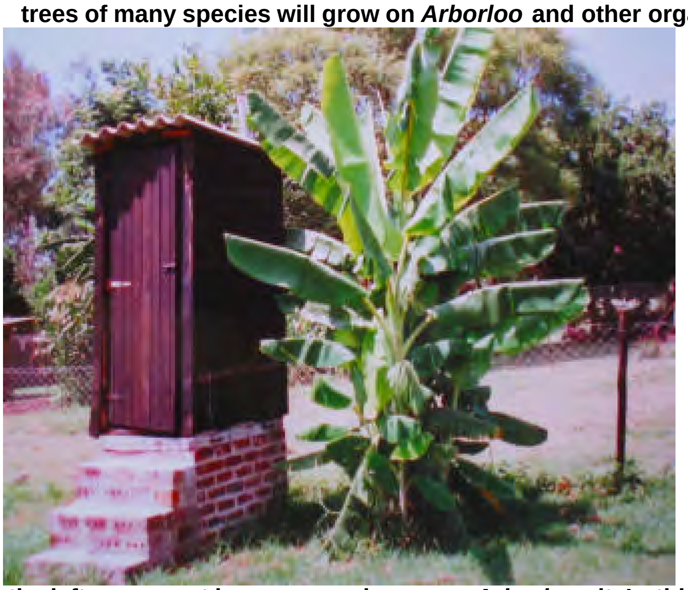

A fine paw paw grows on an *Arborloo* pit, now 4 years old. On the right bananas have been planted on a series of old *Arborloo* pits in this garden. These are also 4 years old.


An avocado tree, about 3 years old. On the right an orange tree between 2 and 3 years old. Peach and guava trees have also grown well on *Arborloo* pits at Porta Farm.

Further photos of trees growing on "organic" pits

A guava tree at Eco-Ed Trust on *Arborloo* pit, Mutorashanga, Zimbabwe.

Variety of trees growing in a sanitary orchard at the Friend Foundation in Harare, Zimbabwe. Indigenous trees of many species will grow on *Arborloo* and other organic pits like this *Swartzia sp* (right)



On the left a rampant banana growing on an *Arborloo* pit. In this case the timber structure alternates as an *Arborloo* and a *Fossa alterna*. Earlier in its life the structure was placed at ground level over a shallow pit protected with a ring beam. A banana was planted on the used pit which filled. Later, after a period of flooding, the structure was elevated onto an above-the-ground vault. The vault contents later turned into humus. Banana is planted on old latrine pits in several African countries like Malawi, Mozambique, Kenya and Rwanda. On the right a huge banana plant grows on an old latrine pit in Epworth, close to Harare.


On the left a healthy gum tree grows on an organic pit at the Friend Foundation in Harare. On the right a healthy paw paw tree is growing. In both cases the trees are growing on a mix of dog manure and soil. As with the *Arborloo,* the pit is filled first with a mix of "manure" and soil, and when nearly full is topped up with a good layer of topsoil. The young tree is planted in the topsoil layer. Mulch is added and the tree is protected from animals. It is then watered thoroughly.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Mulberry growing on an *Arborloo* pit at Kufunda Village, Ruwa, Zimbabwe. On the left at the time of planting during an eco-san course for students. On the right about a year later. Mulberry is a versatile fruit tree to grow on Arborloo pits. It rarely fails to do well. The fruit is both nutritious and tasty. Young trees can be grown from cuttings, making them easy to multiply.


Banana and Passion fruit growing in Malawi

Trees in all their splendour

The green backcloth to a splendid scene of Nature

A mature plantation of gum trees near Rhodes Nyanga Hotel, Zimbabwe.

13. Plant trials using Fossa alterna compost

Poor top soils are so common in Africa, that soil enrichment is essential if any viable growth is to be achieved. Very often cattle manure is used to enhance the soil where it is poor, and this is a very successful method. But cattle are not owned by a considerable proportion of the population, and those living in the peri-urban areas may have no easy access to it. The alternative is to buy and import the manure, make compost or to use inorganic fertilisers. Compost making and application to gardens is a very practical method of solving the problem and must be encouraged (see chapter on gardening techniques). However the inorganic fertilisers are becoming scarce and expensive in Zimbabwe, at least, and they are certainly expensive over much of Africa, and beyond the means of most poor people. So other possibilities must be explored. The possibility of using humus derived from human excreta thus becomes a meaningful and practical option, because it costs almost nothing to produce and its supply is almost guaranteed year by year. As we have seen this can change a barren soil into one which has potential for growing vegetables.

The ultimate proof of the usefulness of eco-humus and urine in agriculture is to demonstrate its effect on plant growth and yield directly. This chapter describes a series of trials in which the growth and yield of vegetables planted in humus derived from the ***Fossa alterna*** were studied**.** In some cases the trials involved comparing the growth of vegetables planted directly in ***Fossa*** humus with plants grown on other soils. However this is an uneconomical way of using the humus. The best method is to mix the humus with less fertile soils.

Comparative growth trial in containers

One of the most rewarding ways of using the humus derived from ***Fossa alterna*** pits is to mix the humus with other soils and grow the vegetables in the mix. This can be done in varying proportions with soil/humus mixes of 1:1 and 2:1 being most practical. For containers, where the soils are contained, the most suitable mixture is a 50/50 mix of topsoil and ***Fossa*** humus. This simple procedure effectively doubles the volume of valuable soil produced and enhances the texture and nutrient level of the original topsoil considerably. Thus it is possible to record the growth of plants in the poor topsoil and compare this with the growth of plants in the ***Fossa*** enhanced topsoil. The use of containers is very convenient for plant trials. When mixing **Fossa** humus with soil in vegetable beds a 2 (soil):1 (humus) mix may be the most suitable.

The primary aim of these trials was to show that by taking humus derived from the family toilet, and by mixing it in equal proportions with poor top soil, a meaningful vegetable production could be achieved where little growth would have been possible before on poor topsoil alone. The addition of ***Fossa*** humus to a poor soil might be regarded as the first stage of soil enhancement. To improve the plant yield further, a second stage of soil enhancement would be required by using manure, compost or liquid plant foods, such as water/urine mix. These trials are revealing - they clearly show that the addition of ***Fossa alterna*** humus to poor topsoil, in equal proportions, can considerably enhance the properties of the topsoil, turning it from a soil in which plants do not grow well into a soil in which viable vegetable production can be achieved.

PLANT GROWTH TRIALS

A simple series of preliminary trials were undertaken to study the effect of the ***Fossa alterna*** humus on plant growth. The trials were undertaken in containers like 10 litre plastic buckets and cement basins. The aim was two fold.

First, to demonstrate the value of the eco-humus as an enhancer of the nutrient level in poor top soils, which are so common in Africa. Soil analyses reveal this improvement.

Second by measuring and comparing the yield of vegetables produced in poor soil and poor soil enhanced by the addition of ***Fossa alterna*** humus, after a fixed number of days of growth. Trials were undertaken with the following vegetables: spinach, covo, rape, lettuce, green pepper, tomato, onion and maize. Only small numbers of plants were used in these preliminary trials, and they must be seen as precursors for more elaborate trials using larger numbers of plants. The trials are described under type of plant.

Nutrient levels of trial soil.

Two types of poor soil were used in the trials, the first from Ruwa, the second from Epworth. The ***Fossa alterna*** humus used in these trials was taken from a single toilet. Final nutrient levels of the 50/50 mix of poor soil and ***Fossa alterna*** soil show an intermediate position between the samples as shown in the table. All samples were analyses using the method described in the earlier chapter.

Soil analysis	**pH**	**N**	**P**	**K**	**Ca**	**Mg**
1. Ruwa soil	5.5	27	5	0.29	:10.23	4.11
2. Fossa humus	6.5	319	196	3.26	:13.70	7.26
Result of 50/50 mix.	**6.4**	**91**	**247**	**0.88**	**3.05**	**2.49**

Soil analysis	**pH**	**N**	**P**	**K**	**Ca**	**Mg**
1. Epworth soil	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**
2. Fossa humus	**6.3**	**197**	**299**	**2.94**	**26.64**	**4.77**
Result of 50/50 mix.	**6.4**	**78**	**356**	**1.01**	**15.75**	**1.78**

Note in both examples there is a considerable increase in nitrogen, phosphorus and potassium in the poor soil after it has been mixed with ***Fossa alterna*** soil. This is to be expected. However the exceptionally high levels of phosphorus in the resulting soils, which are consistent and have been found in other analyses cannot be explained.

The plant trials with *Fossa alterna* humus applied to poor soils

SPINACH – Trial 1.

Spinach is an adaptable plant and grows well on many soils. The initial trials with spinach were conducted in ten litre cement basins in which vegetable seedlings were planted in either poor (Ruwa) topsoil or the same topsoil mixed with an equal proportion of ***Fossa*** humus. The following figures show the weight of spinach grown over a 3 month period (July-Oct. 2002).

The photo shows 18 gms of spinach grown on poor Epworth soil (right) compared to 180gms of spinach grown on Epworth soil enhanced with *Fossa* soil (left), after a 3 month growth period.

SPINACH – Trial 2.

In a further series of trials, spinach seedlings were planted in 10 litre buckets containing Epworth soil and a mix of Epworth soil and ***Fossa*** humus. The soil from Epworth (a peri-urban settlement of some 100,000 persons close to Harare) is notoriously poor, and most residents are unable to grow crops in their gardens. Those that do must import manure or use commercial fertiliser. Significant improvements in growth were measured for spinach, covo and lettuce by enhancing the poor Epworth soil with ***Fossa alterna*** humus.

Growth/weight/yield of spinach produced in 10 litre buckets (gms)
(mean of 3 plants in each of 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)
Leaf wt after 30 days (buckets 1&2)	243gms	32gms
Leaf wt after 30 days (buckets 3&4)	303gms	40gms
Total	**546gms**	**72 gms**

Note below weights of individual spinach (on 30 day trial)
On Epworth (poor soil) : 11, 10. 11, 20, 10, 10, Total (T) 72gms, Sample no (N) =6, Mean (M) = 12gms, Standard deviation (SD) = 3.95,

On 50/50 Epworth/Fossa alterna soil : 85, 80, 78, 118, 110, 75, Total, 546 gms, Sample no = 6, Mean = 91 gms, Standard deviation (SD) = 18.29.

The two samples are significantly different at the 95% level of confidence.

Thus the yield of spinach on Epworth soil was increased over 7 times as a result of enhancing it with ***Fossa alterna*** soil, without further enhancement. An analysis of the Epworth soil, the ***Fossa*** humus and the resulting mix is shown earlier. In a settlement like Epworth, such an enhancement would be regarded as very significant. In effect the *Fossa* humus turned a meaningless yield on poor soil to a meaningful yield on enhanced soil. In the case of spinach, this first crop was reaped and the plant continued to yield more leaves for further cropping.

The photo shows spinach grown on poor Epworth soil (left) compared to spinach grown on Epworth soil enhanced with *Fossa* soil (right), after 30 day growth period. The increase is seven fold.

COVO - Trial 1.

Covo is a popular vegetable in Zimbabwe and also in the sub region (e.g. Mozambique). Its leaves are tasty, and can be cropped from the main stem for a two year period. It is resistant to drought and copes quite well in poor soils. It can also be planted from cuttings. In this trial three covo seedlings were planted in neat ***Fossa alterna*** soil in a 10 litre cement basin and the growth was compared to identical seedlings planted in the poor soil from Epworth.

The photo shows 20 gms of covo grown on poor Epworth soil (right) compared to 161gms of covo grown on neat *Fossa* soil (left), after a 30 days growth period. This is an eight fold increase in yield.

Note below weights of individual covo (trial 30 days)
On Epworth (poor soil) : 10, 2, 8. Total 20 gms. Sample no =.3, Mean = 6.66gms, SD =4.16
On 50/50 Epworth/Fossa alterna soil : 62, 49, 50. Total 161gms, Sample no =.3, Mean = 53.66, SD = 7.23

The two samples are significantly different at the 95% level of confidence.

COVO - Trial 2.

In a further series of trials, covo seedlings were planted in four 10 litre buckets, 2 containing the poor Epworth soil and 2 containing a 50/50 mix of Epworth soil and ***Fossa*** humus. Once again significant improvements in growth were measured by enhancing the poor Epworth soil with ***Fossa alterna*** humus. In this case the yield of covo on Epworth soil was increased over 4 times as a result of enhancing it with ***Fossa alterna*** soil. Note this is a first cropping. Covo can be repeatedly cropped depending on soil fertility.

Growth/weight/yield of covo produced in 10 litre buckets (gms)
(mean of 3 plants in each of 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)
Leaf wt after 30 days (buckets 1&2)	180 gms	41 gms
Leaf wt after 30 days (buckets 3&4)	177 gms	40 gms
Total weight	**357 gms**	**81 gms**

Note below weights of individual covo (trial 2 - 30 days)

On Epworth (poor soil) : 11, 10, 20, 20, 10, 10. T = 81 gms, N = 6, M = 13.5 gms, SD = 5.05.
On 50/50 Epworth/Fossa alterna soil : 50, 70, 60, 72, 20, 85. T = 357 gms, N = 6, M = 59.5 gms, SD = 22.66.

The two samples are significantly different at the 95% level of confidence

The photo shows covo grown on poor Epworth soil (left) compared to covo grown on Epworth soil

enhanced with *Fossa* soil (right), after 30 day growth period. The increase is four fold.

RAPE - Trial 1.

1. Growing Rape in a shallow above ground vegetable garden with *Fossa* humus

This trial was undertaken in a one square metre brick enclosure built above ground on a plastic sheet. The soil mixture was made by combining 40 litres ***Fossa*** humus with 40 litres of poor sandy soil from the Ruwa, making a soil depth of only 75- 80 mm. A more suitable volume would have been 50 litres of eco-humus + 50 litres topsoil for this area, making a soil depth of 100mm, which is just adequate for shallow rooted vegetables. The soil was watered and then planted with about 50 rape seedlings. The bed was watered generally twice a day with borehole water only (ie no plant food of any type added). The bed was also covered with shade cloth. Rape seedlings were produced from seed in a seed tray. The growth of rape was good. The same technique could be used over a wider area.

During the growing period of 4 months (June to October 2002) 3.1 kg of rape were reaped from the first and second harvest. Almost the entire nutrient supply for this small garden was derived from the 40 litres of ***Fossa*** eco-humus (the sandy Ruwa soil had almost no nutrients in it). Thus once again we see a very real use for the eco-humus. Almost no growth of the rape took place on Ruwa soil alone on a control basin. If all the ***Fossa alterna*** humus had been used to grow rape about 40 kg would have been produced. In this case, the production could have been enhanced by additional feeding with a 3:1 water/urine mix applied twice a week. However that was not the point of the trial.

In the case cited above, the ***Fossa alterna*** humus was itself a mix of poor soil and excreta only, with no inclusion of leaves or vegetable matter. The nutrients were further diluted by combining with another poor soil. The table below records this sequence. The vegetable output is thus even the more remarkable.

Nutrient levels in soils

Soil source		pH	N	P	K	Ca	Mg
Natural soil added to ***Fossa*** pit	**4.9**	**50**	**13**	**0.18**	**2.95**	**0.78**	
Resulting eco humus from ***Fossa***		**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
Natural soil (Ruwa) added to ***Fossa*** humus		**5.1**	**14**	**23**	**0.10**	**1.12**	**0.48**
Final soil mix	**6.4**	**91**	**247**	**0.88**	**3.05**	**2.49***	

One sees the considerable enhancement of nutrient levels in the soil removed from the ***Fossa*** pit compared to the soil placed into the ***Fossa*** pit. And for the second time, one sees considerable enhancement of nutrient levels in the soil resulting from the combination of this ***Fossa*** humus with a very poor naturally occurring soil (Ruwa). And yet despite being mixed with poor soil twice, the end result was still a positive result for vegetable growth. It is remarkable that with such dilution with poor soils, the nutrients available in the humus excreta can still result in meaningful yields of vegetables without the addition of any further plant food.

Harvest of rape growing in an above the ground vegetable garden.
Almost 100% of nutrients derived from *Fossa alterna* humus

LETTUCE

Three lettuce seedlings were planted in each of 2 X 10 litre buckets containing poor Epworth soil and also 2 X 10 litre buckets containing a mix of Epworth soil and ***Fossa*** humus (50/50 mix). The total weight of lettuce grown after 30 days on the buckets of Epworth soil alone was **122 gms** compared to **912 gms** grown on Epworth soil enhanced with ***Fossa alterna*** humus. This is a 7 fold increase in production of the poor soil as a result of enhancing it with ***Fossa alterna*** humus.

Growth/weight/yield of lettuce produced in 10 litre buckets (gms)
(mean of 3 plants in each of 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)

Total wt. after 30 days (buckets 1&2)	447 gms	56 gms
Total wt after 30 days (buckets 3&4)	465 gms	66 gms
TOTAL	**912 gms**	**122 gms**

Note below weights of individual lettuce (30 day trial)

On Epworth (poor soil) : 15, 20, 21, 25, 19, 22: T = 122 gms, N = 6, M= 20.33 gms, SD = 3.33
On 50/50 Epworth/Fossa alterna soil : 130, 160, 157, 150, 155, 160,. T= 912 gms, N = 6, M = 152 gms, SD = 11.40
The two samples are significantly different at the 95% level of confidence.

The photo shows lettuce grown on poor Epworth soil (left) compared to lettuce grown on Epworth soil enhanced with *Fossa* soil (right), after 30 day growth period. The increase is seven fold.

GREEN PEPPER

Most plants thrive on the undiluted eco-humus. The green pepper shown in the photo below has shown exceptional growth when planted in undiluted eco-humus after a 4 months of growth period. In this case the green peppers were grown in ***Fossa*** humus without mixing and comparisons made with identical seedlings grown on a 50/50 mix of ***Fossa*** humus and Ruwa soil and also in the basic Ruwa soil. The photos reveal the huge difference in growth. The weight of green peppers produced after 4 months on neat ***Fossa*** soil was **415 gms** (first crop). This compared to **89 gms** produced on the 50/50 mix of Fossa and Ruwa soil and only **19 gms** on the Ruwa soil only. The minuscule production on the Ruwa soil, reveals now poor it is as a growing medium for plants.

Weight of Green pepper produced after 4 months

Soil type	Weight produced
Ruwa soil	**19gms**
50/50 mix of Ruwa and ***Fossa*** soil	**89 gms**
Fossa soil without dilution	**415 gms**

These figures reveal that some hardy plants like green pepper can grow well in undiluted ***Fossa*** compost. However the compost is rich and best diluted with an equal or larger volume of top soil. It is not only the nutrients in the soil which are important to ensure good growth. Soil texture is also an important factor which determines how well a plant will grow. Experience has shown that by mixing ***Fossa alterna*** humus with most top soils including sandy soils and red soils improves the texture considerably enabling roots to penetrate the media more. Thus by mixing the eco-humus with other soils, the texture of the parent soil may be improved as well as nutrient level.

Green pepper growing on buckets of undiluted *Fossa* soil (left), poor Ruwa soil (right) and a 50/50 mix of the two (centre). A 20 fold increase in yield from poor to rich soil

TOMATO

Initial trials were conducted in ten litre cement basins in which vegetable seedlings were planted either in poor topsoil (Ruwa) or the same topsoil mixed with an equal proportion of ***Fossa*** humus (5 litres + 5 litres). The following figures show the weight of tomato grown over a 3 month period (July - October 2002) in each ten litre basin.

	Fossa soil and poor mixed 50/50	Poor soil only (Ruwa)
Tomato	**735** gms	**73 gms**

Note below weights of individual tomato (harvested after 3 months)

On Ruwa soil (poor soil) : 33, 10, 30. T= 73gms, N = 3, M = 24.33, SD= 12.62
On 50/50 Ruwa soil/Fossa alterna soil: 20, 40, 50, 60, 50, 50, 40, 50, 40, 50, 40, 50, 40, 45, 50, 30, 30. T = 735 gms , N = 17, M = 43.23, SD = 9.83

The two samples are significantly different at the 95% level of confidence.

A ten times yield in tomatoes was obtained by mixing eco-humus with the poor topsoil which was itself unable to produce any meaningful growth of tomato at all. However the nutrients held in 5 litres of ***Fossa*** humus led to the reaping of 735 gms tomatoes. The full 500 litres of annual output of humus might have let to a crop yield of 73.5 kg tomatoes. However in this particular trial, the total yield of tomatoes, even in the mixed soil was well below which could be expected from well manured or fertilised soil. Special techniques are required to get the best crop of tomatoes. They require a rich soil, with plenty of potassium in the later stages of growth to promote full fruit development.

MAIZE

Maize is certainly the most important crop grown in Southern and Eastern Africa and a study of its reaction to eco-humus is important. In this trial, comparisons were made with maize grown in poor Epworth soil and Epworth soil enhanced with ***Fossa alterna*** humus (50/50 mix).

Maize seedlings were planted in four 10 litre buckets, 2 containing poor Epworth soil and 2 a mix of Epworth soil and ***Fossa*** humus (for soil analysis - see early in chapter). The maize seedlings were planted on 28th September Significant growth was initially observed in the Epworth soil enhanced with ***Fossa alterna*** humus. The growth of maize on the plain Epworth soil was very poor by comparison. However by 5th November, nutrient deficiency was beginning to reveal itself, even in maize plants growing on ***Fossa*** enhanced Epworth soil - with the oldest leaves on the maize showing some signs of yellowing (an indication of reduced nutrient availability), as the nutrients in the basin were used up. When a plant like maize starts to struggle for nutrients, the available nutrients are directed to the youngest leaves, and withdrawn from the oldest - which shows up as yellowing in the basal leaves, lightening in colour of all leaves and subsequently as a reduced yield of maize cobs. The full potential of growth was never reached in any of the 12 maize plants grown in this trial. After about 3 months of growth the cobs were removed from the plants, stripped of their covering and weighed. The following data was recorded.

Growth/weight/yield of Maize produced in 10 litre buckets (gms)
(mean weight of 6 plants in 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)
Mean cob wt after 3 month	**18.33 gms**	**0.41 gms**

The cobs produced in all plants in this trial were very low weight. Cob weights for maize grown on ***Fossa alterna*** /Epworth soil combinations were **30, 10, 20, 30, 14,** and **6** gms respectively (one per plant). Cob weights for maize grown on Epworth soil were **2 gms** and **0.5gms only**. This reveals the exceptional poor nutrient value of the soil in Epworth (near Harare) where at least 100,000 people live. ***Fossa alterna*** humus did enhance the output, but not nearly sufficiently to produce a meaningful yield.

Although adding *Fossa* humus to Epworth soil enhanced the growth of maize, this was not sufficient to produce a meaningful crop. Urine treatment is required to gain good maize harvests from poor soil.

Maize is the most important food crop grown in Southern and Eastern Africa and requires a considerable nutrient input for grow to its full potential. The relatively small volumes of eco-humus produced in the ***Fossa alterna*** annually (about 500 litres)**,** particularly, when they are combined with an equal volume of naturally occurring top soils (to make 1000 litres), are sufficient to sustain a good annual production of vegetables in the backyard. But this eco-humus by itself is quite insufficient to have an influence on crops like maize plants, which are grown in large numbers and are hungry feeders. The conclusion to be drawn is that ***Fossa*** humus is more productively used in growing vegetables in the backyard, rather than enhancing maize growth. Maize responds very well to the application of urine

The best way of enhancing maize growth is in two stages. Improving the nutrient and humus content in the top soil first (by adding eco- humus or manure) and then elevating and sustaining the nutrient level further by the further application of a liquid feed like urine and water. The use of urine as an enhancer of plant growth, including maize is described later in this book.

ONION

Early trials were conducted in ten litre cement basins in which onion seedlings were planted either in very poor topsoil from Ruwa or the same topsoil mixed with an equal proportion of ***Fossa*** humus. The following figures show the weight of plants grown over a 4 month period (July - November 2002 - trial 1 and August - December - trial 2).

Weight of onion produced in 10 litre basin (gms)

	Fossa soil and poor (Ruwa) mixed 50/50	Poor soil only (Ruwa)
Onion (trial 1)	**391 gms** (10 plants)	**141 gms** (9 plants)
Onion (trial 2)	**558 gms** (10 plants)	**271 gms** (10 plants)

Note below weights of individual Onions (harvested after 4 months)

Trial 1.

On Ruwa soil (poor soil) : 38, 15, 18, 10, 8, 18, 10, 8, 16. T = 141 gms, N = 9, M = 15.66, SD = 9.30

On 50/50 Ruwa soil/ Fossa alterna soil: 47, 20, 55, 41, 58, 26, 29, 40, 45, 30. T = 391, N = 10, M = 39.10,

The two samples are significantly different at the 95% level of confidence.

Trial 2.

On Ruwa soil (poor soil) : 42, 40, 5, 40, 22, 30, 5, 40, 30, 29. T = 271, N = 10, M = 27.1. SD = 14.65

On 50/50 Ruwa soil/ Fossa alterna soil: 92, 80, 60, 40, 20, 80, 70, 50, 40, 20. T = 558, N = 10, M = 55.8, SD 25.82.

The two samples are significantly different at the 95% level of confidence.

Normally onion should be left to mature for 6 months, at least, to gain maximum weight. In these trials onions were weighed early to give a comparison between the growth potential on onion of poor soil and also soil enhanced with ***Fossa alterna*** humus. In both cases the onion yield was at least doubled by the addition of ***Fossa*** eco-humus to the poor Epworth soil. In fact the best mix for onion is to plant in rich soil mixed with leaf mould and to feed regularly with a water-urine mix. In much richer soils fed with a water-urine (3:1) feed, twice or three times a week, 1.4 kg of onion can be produced in a 10 litre basin in a 4 month period (see urine trails). The ***Fossa alterna*** soil, when mixed with poor soil does not provide the ideal medium for impressive yields of onion or maize by themselves. However, supplemented with urine, they can produce excellent crops.

The reaped onions reveal the enhancing effect of *Fossa alterna* humus on very poor top soils. The yield on poor Ruwa soil (141 gms) has been increased to 391 gms in *Fossa* enhanced Ruwa soil, an increase of nearly 3 times. This is a significant increase in onion production. However the best onion crops are produced on very rich organic soil. They are hungry feeders.

Plant trials with *Fossa alterna* soil on an existing vegetable bed

This trial was carried out at Woodhall Road between November 2003 and January 2004 to test the influence of ***Fossa alterna*** soil (with and without urine application) upon an existing vegetable bed. The addition of ***Fossa alterna*** soil to an existing bed is perhaps one of the most likely methods of using the humus. The influence of both eco-humus and urine will vary greatly depending on the existing state of the soil and the plant. Where nutrient levels are depleted, the influence may be considerable. Where nutrient levels are adequate, the effect will be less noticeable. In this case existing nutrient levels were quite high in the soil.

In this case, the influence of the humus and urine was tested on two green vegetables, rape and spinach, which are both popular in Zimbabwe. The existing bed was re-dug and soil mixed as best as possible and divided into three equal sections, A, B and C. Each bed measured 1.5m X 3.5m (5.25 sq.m.). ***Fossa alterna*** soil was applied to two of the beds (A and C) at the rate of 12 X 15 litres spread over the bed and mixed into the topsoil (see chapter). Local topsoil was applied to the centre bed (B), also at the rate of 12 X 15 litres spread over the whole bed and mixed in. 25

spinach and 25 rape plants were planted in each bed (on 22nd November). These were watered regularly to keep in good health. After 11 days urine treatment started on bed C with a 3:1 mix being applied to the bed, three times per week (2 X 8 litres per application). At all other times all beds were watered in the same way. Soil samples of the ***Fossa alterna*** humus were analysed on several occasions, with two samples being analysed from each bed before planting and after initial watering. Further samples were taken after urine application (see later chapter).

During the trial there was no evidence of nutrient deficiency in any of the beds, even in the centre bed (B). This shows that the bed already had sufficient nutrients to sustain vegetable production, as would be expected in an existing bed. The aim was to demonstrate any additional benefit from the addition of humus and urine.

Results

All the vegetables were harvested on a single day 28 days after the initial application of urine to bed C. Each plant was harvested and weighed. Since both spinach and rape can be harvested several times a single small leaf was retained by the plant after cutting to allow the plant to continue to grow. The results of the first harvest are shown below. In a few cases plants were taken by rats and a low plastic wall was built around the vegetable garden.

Bed A (topsoil+ecohumus)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	4153 gms	25	166.12 gms
Rape	2478 gms	23	107.73 gms

Bed B (topsoil)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	2349 gms	24	97.87 gms
Rape	1928 gms	25	77.12 gms

Bed C(topsoil+ecohumus+urine)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	3918 gms	24	163.25 gms
Rape	2488 gms	23	108.17 gms

The vegetable garden associated with the *Fossa alterna* at Woodhall Road. On the left, the day of planting vegetables 22nd November 2003. 25 spinach and 25 rape seedlings were planted on each of the 3 beds. The bed on the extreme left and right have been enhanced with *Fossa alterna* soil. The bed in the centre has existing topsoil. The right photo shows the state of the beds on 10th December.


The beds the day before harvesting on 30th December 2003. Vigorous growth is seen throughout. The bed improved with *Fossa alterna* soil showed an increase of 70% for spinach production and 40% for rape production over the unimproved bed, which was already clearly good. On the right harvesting and measuring each plant (see results below).

1. Plant growth

In the bed mixed with extra ***Fossa alterna*** soil, spinach harvest was increased by 1.7 times (after 4 weeks) and rape 1.4 times (after 4 weeks), despite the existing bed being already quite adequate in terms of soil nutrients. After 6 weeks and two croppings the increase had been reduced slightly to1.6 times (spinach) and 1.3 times (rape). After 8 weeks and three croppings the total weight of spinach cropped on Bed A was 4754 gms, compared to 3027 gms on Bed B and 4425 gms on Bed C. After 8 weeks and three croppings the total weight of rape cropped on Bed A was 3233 gms, compared to 2736 gms on Bed B and 2698 gms on Bed C. Thus overall the application of the humus increased the spinach crop by 1.57 times and the rape crop by 1.18 times.

However the application of urine in this particular case does not seem to have had much beneficial effects on the overall growth of either rape or spinach. This negligible effect may have been the result of either an over application of urine, or an application which was in excess of what the plants required. In this case both appear applicable, as existing levels of NPK were quite adequate without any further urine application being necessary. Towards the end of the trial vegetables planted in the urine fed bed were beginning to die out, no doubt due to over feeding with nitrogen derived from urine. 3 weeks after the second cropping all the rape plants had died out. This will be discussed in more detail in the section on plant trials with urine.

The results of this trial also reveal that the extra nutrients provided by the ***Fossa alterna*** humus do not sustain increased plant growth for much over 2 months, and the main effect is during the month following application of the humus. The figures show a depletion of both spinach and rape output after successive croppings. This would be expected to be generally the case for plants that are cropped repeatedly. But in urine fed basins, crop output of spinach was maintained at a high level during the second month of cropping spinach when the current trial was running. This indicates a depletion of nutrients in the soil or adverse conditions for growth in the chosen bed. Clearly the best option for beds is combine the use of both ***Fossa alterna*** humus and diluted urine to the beds to sustain maximum output throughout the year. As indicated earlier, the application of other organic materials like leaf or garden compost to the bed also helps production greatly. Note that the addition of humus, not only adds nutrients but provides a better soil environment for the application of urine.

The bed used in this case was surrounded by trees so full sunlight came later in the morning and was not identical for each of the beds with the centre bed being the most sunned. The growth potential for all plants including vegetables depends on a variety of factors of which soil fertility is an important one. Regular watering, either by natural rainfall or by artificial watering is essential for a good crop. Also the best crops are produced where there is plenty of sunshine. In the present case, the sun did not arrive on the bed until mid to late morning, and this would have had an overall reducing effect on the final production.

Individual weights

BED A. Spinach gms.
90,65,110,120,188,174,188,103,173,263,170,160,260,175,169,218,150,258,160,240,228,138,90,213,50. T=4153. N= 25. M=166.72.

BED A. Rape gms.
149,28,58,52,23,198,185,220,140,55,128,42,111,130,22,104,78,70,131,156,118,242,38. T=2478. N=23. M=107.73.
BED B. Spinach gms
100, 90, 102, 124, 80, 83, 130, 98, 58, 102, 138, 184, 40, 70, 192, 91, 58, 132, 70, 90, 110, 60, 42, 105. T=2349. N = 24. M= 9787.
BED B. Rape gms
60, 130, 42, 128, 47, 70, 38, 60, 46, 60, 170, 142, 58, 90, 62, 100, 72, 118, 35, 48, 86, 37, 87, 40, 102. T=1928. N= 25. M=77.12.
BED C. Spinach gms
82, 34, 110, 40, 179, 100, 268, 202, 368, 211, 115, 178, 198, 423, 153, 183, 177, 118, 249, 128, 50, 99, 42, 211. T=3918. N=24. M=163.25.
BED C. Rape gms
162, 222, 100, 142, 122, 130, 49, 82, 163, 39, 135, 60, 50, 47, 60, 34, 90, 189, 61, 37, 207, 140, 167. T=2488. N=23. M=108.17.

Second harvest

Both spinach and rape can be harvested several times from a single plant if the conditions are suitable. In this case the initial crop was cut and weighed from beds A, B and C four weeks after urine application (on bed C). A second crop was cut and weighed 2 weeks later (after 6 weeks of urine application on bed C) and about 7-8 weeks after planting. The second crop cut 2 weeks after the first crop was much less than the initial crop as shown below.

Bed A (topsoil+ecohumus)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	429 gms	19	22.57 gms
Rape	576 gms	18	32.00 gms

Bed B (topsoil)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	508 gms	20	25.40 gms
Rape	622 gms	22	28.27 gms

Bed C(topsoil+ecohumus+urine)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	405 gms	17	23.82 gms
Rape	210 gms	10	21.00 gms

Third harvest

A third small crop was cut and weighed 4 weeks after the first harvest, 2 weeks after the second harvest and 8 weeks after initial urine application on bed C). The second crop cut 2 weeks after the first crop was much less than the initial crop and the second crop as shown below.

Bed A (topsoil+ecohumus)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	172 gms	12	14.3 gms
Rape	179 gms	14	12.78 gms

Bed B (topsoil)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	170 gms	18	9.44 gms
Rape	186 gms	14	13.28 gms

Bed C(topsoil+ecohumus+urine)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	302 gms	12	25.16 gms
Rape	0 gms	0	0 gms

2. Nutrient levels

The humus derived from the ***Fossa alterna*** was high in all major nutrients as the 2 initial samples show (mean N: 655, mean P: 296, mean K: 5.26). This was mixed with the existing vegetable bed soil at a rate of 2 parts garden soil to one part ***Fossa*** humus. The resulting mixed soil contained NPK as follows. Bed A (mean N: 207, mean P: 325, mean K: 4.16). Bed C (mean N: 367, mean P: 328, mean K: 1.42). By comparison the existing vegetable garden soil contained NPK as follows. Bed B (mean N: 304, mean P: 316, mean K: 1.37).

All 3 beds were then thoroughly watered and planted with seedlings and then re-watered again. After a few days the soil was sampled again. This time the results were as follows: Bed A (mean N: 253, mean P: 308, mean K: 2.02). Bed C (mean N: 367, mean P: 305, mean K: 2.89). By comparison the existing vegetable garden soil contained NPK as follows. Bed B (mean N: 116, mean P: 156, mean K: 1.04). Thus as the plants were growing the application of the eco-humus had increased the NPK levels significantly, but even existing levels were quite adequate for normal plant growth. After a further 4 weeks, and the day before cropping, further samples were taken. The results were as follows: Bed A (mean N: 151.5, mean P: 323, mean K: 1.73). Bed B: (mean N: 97.5, mean P: 259, mean K: 0.79). By comparison, bed C after 4 weeks of urine showed: mean N: 199.5, mean P: 302, mean K: 1.65). No sample showed any sign of a lack of nutrients. All samples were quite adequate for plant growth.

Soil analysis (N, and P as ppm and K, Mg and Ca as ME/100gms)

Fossa alterna soil	pH	N	P	K	Ca	Mg
Sample 1.	6.8	720	307	3.32	27.04	13.08
Sample 2.	6.8	590	286	7.20	27.56	12.80

Bed samples before watering

Bed A	ph	N	P	K	Mg	Ca
Sample 1.	7.1	214	331	6.75	34.78	5.13
Sample 2.	7.4	200	320	1.58	32.64	4.98

Bed B	pH	N	P	K	Mg	Ca
Sample 1.	7.1	275	329	1.40	31.10	4.77
Sample 2.	7.1	333	304	1.34	33.74	4.93

Bed C	pH	N	P	K	Mg	Ca
Sample 1	6.8	294	358	1.26	24.58	4.70
Sample 2.	7.1	174	298	1.58	32.46	4.61

Bed samples after watering

Bed A	pH	N	P	K	Mg	Ca
Sample 1.	6.9	295	289	1.32	26.66	8.00
Sample 2.	7.0	211	327	2.72	30.32	6.88

Bed B	pH	N	P	K	Mg	Ca
Sample 1.	7.0	118	176	0.99	17.74	3.44
Sample 2.	7.0	115	137	1.10	12.45	2.91

Bed C	ph	N	P	K	Mg	Ca
Sample 1	7.0	400	296	3.44	30.42	7.90
Sample 2.	6.7	334	315	2.34	33.02	8.00

Bed samples – 4 weeks after urine treatment to Bed C.

Bed A	pH	N	P	K	Mg	Ca
Sample 1.	6.9	160	312	1.65	24.96	7.26
Sample 2.	7.0	143	334	1.82	29.62	6.20

Bed B	pH	N	P	K	Mg	Ca
Sample 1.	7.2	119	341	0.82	31.08	4.46
Sample 2.	6.9	76	177	0.77	13.45	3.25

Bed C	pH	N	P	K	Mg	Ca
Sample 1	6.4	217	290	1.50	19.49	5.06
Sample 2.	6.7	182	314	1.80	27.60	5.76

Overall conclusions

These simple plant trials reveal the considerable value of humus derived from the ***Fossa alterna*** when applied to very poor sandy soils in equal proportions in containers (see table below). The effect is also positive even when applied to existing vegetable beds, at a ratio of one part ***Fossa alterna*** soil to two parts top soil, although the increased yield is less. Every year a single family ***Fossa alterna*** will provide at least 0.5 cubic metres of humus which can be mixed with an equal volume of very poor topsoil to make one cubic metre of suitable planting medium for vegetables. This one cubic metre mix of rich soil will provide enough material to fill 100 ten litre buckets or basins, or 7 shallow trenches (each 3 m long, 0.3m wide and 0.15m deep), or about 10 square metres of shallow vegetable garden, about 10cm deep. At the slightly lower rate of application of 2 parts topsoil to l part humus about 16 sq.m. of vegetable bed can be invigorated.

The production of vegetables from such a back yard vegetable garden might be considerable. Using figures revealed in from the trials in containers, one can estimate that **27 kg of spinach** (first crop only at least two crops can be reaped) or **17 kgs of covo** (first crop only - covo can be cropped for an extensive period) or **37 kg rape** or **45 kg lettuce** or **41 kg green pepper** or **73 kg**

tomatoes or **40- 50 kg onion** could be grown on the annual output of ***Fossa*** humus mixed with local topsoil. Obviously there would be a mix of these crops produced in practice. As can be seen from the equivalent weight of vegetables grown on poor soils alone, this is a remarkable enhancement in vegetable production compared to what have been possible without the eco-humus. Crop yields are consistently increased by adding eco-humus to poor soils from doubling to over a ten fold increase. However the actual increase in yield would depend on the existing nutrient status of the treated vegetable bed. For an already fertilised bed, one could expect an increase in yield of about 50%.

Summary of plant trials in containers described in this chapter.

Plant. Top soil type. Growth period.	Weight at cropping Top soil only	Weight at cropping 50/50 mix topsoil/FA*soil
Spinach on Epworth 30 days.	72 grams	546 grams (7 fold increase)
Covo on Epworth 30 days.	20 grams	161 grams (8 fold increase)
Covo 2. on Epworth 30 days.	81 grams	357 grams (4 fold increase)
Lettuce on Epworth. 30 days	122 grams	912 grams (7 fold increase)
Onion on Ruwa 4 months	141 grams	391 grams (2.7 fold increase)
Green pepper on Ruwa 4 months	19 grams	89 grams (4.6 fold increase)
Tomato on Ruwa 3 months	73 grams	735 grams (10 fold increase)

Whilst such an output would not sustain the family throughout the year, it is a meaningful contribution to vegetable crop yield, and in areas which are deprived would be seen as valuable addition to the family's food supply. Since the value of the humus must be seen in addition to the value of the improved and long lasting nature of the sanitary facility itself, the overall benefit is considerable.

As with all methods which take advantage of fertile soil for vegetable production, the soil nutrients do become depleted as they are used for plant growth. Therefore the fertility of the soil itself must be restored by re-mixing with more recently made eco-humus or with other compost. In this way the fertility of the soil is maintained - what is taken up by the plants is put back. This is the best way of maintaining a healthy annual crop of vegetables.

Another important point to mention is that the results shown in this chapter apply mostly to ***Fossa alterna*** soils mixed with naturally occurring soils of exceptionally poor quality. Sadly such soils are common where people live in many parts of Africa. Epworth, one source of the poor soil used in these trials, comes from an area close to Harare where over 100 000 people live. Ruwa is typical of so many other sandy areas in Zimbabwe where huge numbers of people live where the soil has been depleted of nutrients, as a result of erosion, leaching and constant use of land without re-fertilisation. In Zimbabwe 70% of rural farmers work on a soil which is labelled as poor or very poor in terms of the nutrient and humus content. Most soils are sandy and have a low pH. Few soils in the rural and even peri-urban and urban areas can sustain any form of healthy crop production without meaningful inputs of both humus and nutrients (Farai Mapanda (pers.comm). Thus any form of fertile soil which can be locally produced and mixed with the poor local topsoil can only be seen as advantageous.

In all these cases, there is an urgent need to replenished the fertility of the soil. This can be achieved by cattle manuring or composting where alternative means are too expensive. It is in such places that the value of the humus derived from the ***Fossa alterna***, maybe most eagerly sought. Obviously where ***Fossa alterna*** humus is used on garden soils which already hold higher level of nutrients, then the effects will be less dramatic than those described in this chapter (see later chapter). The important point is that ***Fossa*** humus does contain meaningful amounts of valuable nutrients which are important to plant growth and by applying them to any soil, the nutrient levels are restored or increased. In addition the physical condition of the natural soil is improved where ***Fossa alterna*** humus is added. Thus what ever soil is considered the overall effect is one of enhancement and improvement.

Yet another important point to stress is that the annual production of eco-humus from the family latrine (***Fossa alterna***) is only sufficient to enhance the family backyard vegetable garden and no more. But this backyard production of vegetable matter can be increased significantly in areas where the soil is poor. The results also reveal that the eco-humus may have limited application with crops like maize, which are grown in very large numbers. But there is nothing to stop the gardener enhancing the effects of the eco-humus further by applying urine. This can be applied in diluted form to vegetable gardens or neat to maize in the fields. This can produce excellent results with maize as well as green leafy vegetables, as we shall see later. Also garden compost, manure, leaf compost and other liquid feeds should also be used to enhance the soil and subsequent vegetable production. Extra nutrients can be provided by inorganic fertilisers, but these will not be used to any extent in the organic farming promoted by eco-san. In fact it would be normal practice to add liquid feeds or manure or compost in the vegetable garden to produce optimal growth of vegetables.

In addition, the process operating in the ***Fossa alterna*** is entirely natural, and the humus which is withdrawn is nothing less than a marvel of Nature. A strong link is made between the sanitation and agriculture. The latrine becomes a humus factory. The second pit of the ***Fossa alterna*** can be used as a pit composter during the first year or it can be used as a site to make leaf mould. This leaf mould alone can make considerable improvements to poor soils.

The potential for this system is enormous. The ***Fossa alterna*** is cheap to build and easy to maintain and there is a valuable end product. But the routine upkeep of the ***Fossa alterna*** does require more effort and attention than the standard pit latrine. The excavation and mixing and reuse of the eco-materials in agriculture requires time and determination. It is hoped that the return of improved yields of food will make all the effort worthwhile. In a world where the soils are poor and there is always a need for more food, such an effort is surely worthwhile.

The 10 litre cement basin proved to be a useful container to conduct plant trials. Here the poor growth of rape on poor Epworth soils (left) is compared with the much improved growth of rape on the same poor soil enhanced with *Fossa alterna* humus. In almost every case the difference is striking. The influence of the humus is particularly noticeable on very poor sandy soils, which are very common in Africa. The humus applied to sandy soils also helps the process which enables the nutrients in urine to enhance vegetable growth. *Photo by Brian Mathew.*

14. The usefulness of urine

Urine has been used as a valuable plant food for centuries in many parts of the world, particularly in the Far East. It is surprising therefore that nearly all the urine produced in the West and in Africa goes to waste and is lost to agriculture. Each of us passes about 1.5 litres of urine every day - and almost to the last drop, it is either flushed down a toilet or enters a deep pit latrine. The fact is that urine is a very valuable product - in several ways. It contains a lot of nitrogen and also phosphorus and potassium in smaller quantities, nutrients which are very valuable to plant growth. Simply put, urine is too valuable to waste.

The nitrogen found in abundance in urine is good for plant growth because it helps to build protoplasm, protein and other components of plant growth. It certainly promotes leafy growth. Leaves become more numerous, go greener and larger and more fleshy with urine application. Phosphorus is important in the root formation, ripening of fruits and germination of seeds, although the percentage of phosphorus compared to nitrogen in urine is low. Potassium is also essential for promoting good fruit (and flower) development. Plants differ in their requirements, but overall plants fed with some urine grow better than plants which never come into contact with urine. Urine is particularly valuable for grasses like maize and leafy green vegetables, and onions, which respond to the high nitrogen content of urine.

Methods of collecting urine

By far the simplest method of collecting and storing urine is for men to urinate in bottles when they visit the toilet. There are several other methods which can be used - the "desert lily" concept is one - where a funnel is mounted over a plastic drum in some position which allows the passing male to urinate in privacy. The simplest are funnels mounted over 20 litre plastic containers. Piping, fittings and containers should be made of plastic - the urine is very corrosive – metal will corrode badly. Various types of urinal can be fitted within toilets built outside.

The urine diverting pedestal is also another suitable method for collecting urine. These pedestals are commonly used in ecological sanitation projects all over the world. There are variants which allow for squatting as well as sitting. The urine diverting pedestal has a pipe which can be used to convey urine into a storage vessel like a 20 litre plastic drum. Care must be taken to ensure that faecal matter does not enter the urine section. Pedestals mounted over removable buckets can also be used to collect urine - they are useful for women. "Potties" filled at night in the bedroom can also collect urine – a well established method. Urine collectors can also be made which fit into conventional flush toilets, the urine being decanted into plastic bottles. Once the urine is collected - it is stored in plastic containers which are capped before use or processing.


Collecting and storing urine in bottles is the easiest way for men. On the left urine stored in discarded two litre milk bottles. A funnel placed over a 20 litre plastic container is also effective if well placed in some private location. It is a type of "desert lily."


On the left a 10 litre bucket is placed beneath a pedestal which helps women to collect urine. On the right a urine collector shaped from a plastic bucket is used to collect urine from a standard flush toilet.

Storage

Urine can be stored in bottles (2 litre plastic milk bottles for instance) or plastic containers (e.g. 20 litres) for long periods provided they are well capped and the ammonia is not allow to escape. Deposits of the phosphorus and magnesium salts will be deposited however on the base and side walls of the container. Once stored, urine usually turns darker. The exact constituents of urine vary from one person to another.

Uses of urine in agriculture

There are at least five ways of using urine for the benefit of agriculture. These are:

1. **Urine applied to soil without dilution before planting**
2. **Urine applied to soil without dilution near the young plant, followed by watering**
3. **Urine applied to soil - diluted with water – to the growing plant**
4. **Urine as an "activator" for compost.**
5. **Urine as a medium for fermentation of plant residues**

Examples of using urine to enhance vegetable production in containers.

Vegetables like covo, rape, spinach and several other green leafy vegetables can adapt to a wide range of urine applications when applied to containers provided that water is also applied liberally. In fact in the case of vegetables and other plants grown on containers, which hold a relatively small volume of soil, it will always be necessary to apply water regularly to sustain plant health, since the volume of water held in the soil is small. On a hot day, the plants will wilt easily, and require frequent watering. With such a constant throughput of water, diluted urine can be applied as frequently as 3 times per week. For use on containers, urine can be diluted with water at the rates of 3:1 or 5:1 and applied once, twice or three times a week. Where there is a large throughput of water in containers it is best to apply in small doses more often then bigger doses less often. Experience has shown that provided fresh water is added to the basin frequently, green vegetables can withstand the 3:1 and 5:1 applications without harm. Generally the rate of growth of green vegetables is in proportion to the amount of urine applied. However in the longer term, a build up of salt occurs, and there may be an excess of nitrogen which will inhibit the uptake of potassium.

For these reasons it is wise to empty the containers of soil treated with urine and remove them to a compost site where the soil can be mixed with other composts and soils and watered without urine application. Thus the soil can be restored and invigorated.

A good standard procedure for green vegetables like rape and spinach growing in 10 litre containers is to apply a 3:1 mix twice a week for the first month, with intermediate watering. Reduce this to a 5:1 mix twice a week for the second month with intermediate watering. From then on apply a 5:1 mix once per week with intermediate watering.

For tomatoes grown in buckets only apply diluted urine after the first small fruits appear. Then apply 0.5 litres of 5:1, once per week with wood ash (add a tablespoon per week to the bucket soil and watering in).

Also for longer term onion (6 months to harvesting) in basins, apply a 3:1 mix twice a week for the first month, with intermediate watering. Reduce this to a 5:1 mix twice a week for the second month with intermediate watering. From then on apply a 5:1 mix once per week with intermediate watering.

Green vegetables respond well to diluted urine treatment

Preparing the urine/water mix

General equipment required for applying urine. Various buckets, watering can, rubber gloves and 0.5 litre jug for dispensing the mix. Supply of urine (in 2 litre plastic bottles). A 5:1 mix can be made with 2 litres of urine and 10 litres water. A 3:1 mix can be made with 2 litres of urine and 6 litres of water.

Add the 2 litres urine first to a larger (20 litre) bucket, then add 10 litres water from the 10 litre bucket.

Apply to the containers from a 0.5 litre jug or similar container. Once or twice a week depending on duration of application. For shorter term (1 – 3 months) on green vegetables, twice a week with plenty of watering in between. For longer term (3 – 6 months) the mix should be applied once a week with plenty of watering in between (tomatoes and onion).

In some applications additional sources of nutrient are mixed in with the urine/water. Like extra phosphate or wood ash applied at the rate of 5gms per 0.5 litre charge of urine and water (5:1). The wood ash supplies extra potassium, particularly suitable for tomatoes.

Mixing in extra wood ash to the jug. 5 gms (level tablespoon) ash per 0.5 litres of 5:1 application. The ash helps to make plants more healthy and is good for fruiting. In this case it is being applied to spinach in an experiment. This type of application is particularly good for tomatoes.

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)

Left: Photo shows 3 basins (on left) which were water fed and on right 3 basins fed with a 3:1 water/urine mix, twice a week. The effect only became noticeable after 10 days treatment. After 28 days water/urine application the effect is very noticeable (photo on right with water treatment below and urine treatment above. Some of the basins are obscured. Rape yield was increased about 5 times.

Left: The relative yields of water fed and water/urine fed rape grown on 10 litre basins after 28 days application. The plants have just been harvested for the first time. Right: the same plants almost a month later just before the second crop was harvested. Yellowing and mauve colour on some leaves begin to show after 2 months of urine application at this rate, indicating that the plants are beginning to weaken. This is probably due to over application of nitrogen from the urine. Longer trials like this provide the best indications of the most suitable water/urine treatment under these conditions. A weaker 5:1 application given to the plants once a week may be better in the longer term

Spinach

Spinach is another popular vegetable in Zimbabwe. 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. This is an excellent response to urine. 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

Photos taken of the 16 basin spinach trial. Basins to the left of the green band are urine fed, those to the right water fed only. Photo on left taken on 3rd December 2003 on the first day of urine treatment. Photo on right taken on 31st December 2003, 28 days after first urine treatment. The effective of the urine treatment is very positive and very clear to see. Urine fed 3.4 times water fed.

Left: The total collected harvest of urine treated spinach on the left and water treated spinach on the right after 28 days of urine treatment (3:1, twice per week). Right: plants fed water/urine during their second month are beginning to lag behind plants fed the 3:1 water/urine mix for the first time. The best yield however is being produced by plants shown on the four basins to the right, which have been fed only two applications of the urine water mix and then leaf compost liquor under a mulch of leaves. These signs show that if urine is to be used as a liquid plant food over a prolonged period, the dose should become weaker as the time is extended. For spinach – first month 3:1, twice a week; second month 5:1, twice a week; third month and thereafter 5:1, once per week. Extended trials show that the lower dose can maintain spinach output, once the soil has been well fertilised by prolonged and correctly applied urine treatment. 0.5 litres of the diluted urine is applied to each basin per treatment. The plants are watered at all other times. Spinach responds very well to this type of treatment.

Onion

Onions are well suited to growing in containers and also respond positively to the application of diluted urine. Onions do take a long time to grow, between 6 to 8 months being required between planting seedlings and harvesting. Seeds are best planted during January or February (for Southern Africa) and allowed to grow in seeds trays. They are transplanted into cement basins when about 4 – 6 weeks old. During this period they can be fed with leaf compost liquor. After transplanting, a weekly application of a urine/water mix (1:5) will help the onion considerably and can begin a week or two after transplanting. Onions need good supplies of nitrogen as well as phosphorus (in the early stages) and plenty of potassium later on. The application of wood ash will help. Planting on a mix of ***Fossa alterna*** humus will help, even better if mixed with compost. A good leaf mulch will help the supply of phosphorus and potassium. The application of leaf compost liquor will also help.

Up to ten onion can grow in a single 10 litre cement basin. Onion are first grown in seed trays, then transplanted to basins. These onion were fed a 3:1 water/urine mix, once a week. They were planted as seedling on 17th May and reaped about 6.5 months later on 27th October 2003. An average of 1 kg of onion was reaped from each of ten jars planted. The number of plants varied between 5 -9 plants at harvest with weights per basin varying from 0.7kg to 1.3 kg. The growth was improved by the application of a mulch made of leaves. This reduced weeds and also provided some nutrients as well as reducing water loss from the soil. The basin and urine method appears to suit onion.


Some very good looking onion can be grown in cement basins with the help of a water/urine feed. Here two prize specimens! Onion seeds are best planted early in the year, late January or February being good times, so they can be transplanted into containers towards the end of the rains in April. The healthy onion on the right was harvested in early September after 6 months of water/urine treatment in a 10 litre cement basin. 0.5 litres of a 5:1 mix of water had been applied once a week for all that period together with intermediate watering. Such a result reveals the usefulness of urine as a plant food.

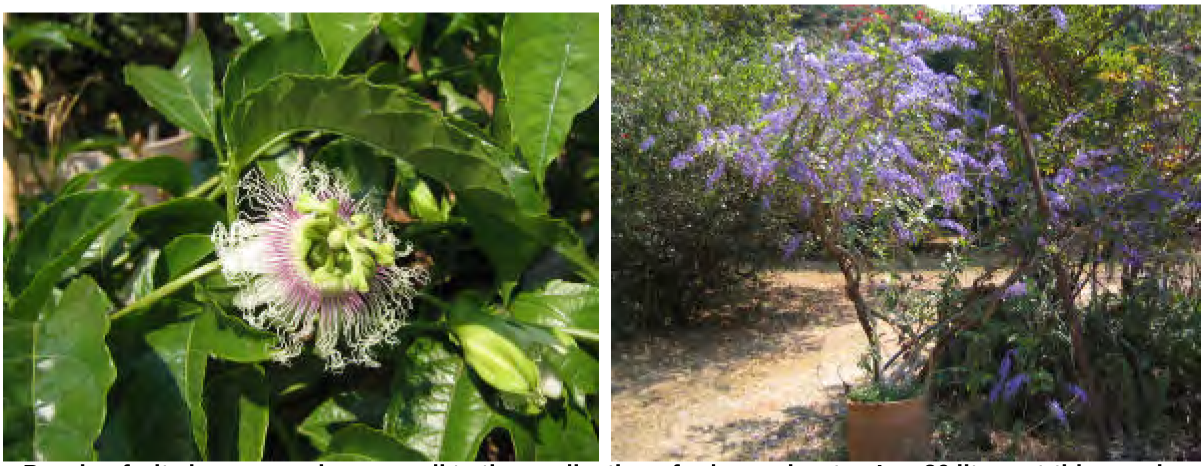
TOMATO

Tomato seedlings will grow in unmixed neat ***Fossa alterna*** humus, but grow better in a 50/50 mix of the humus and garden/leaf compost. The addition of the leaf compost makes the final mix more crumbly and well drained. The soil should be rich in phosphorus to start to help the plants grow sturdy roots and early shoots. When growing in containers most hungry feeders (like tomato, onion and other vegetables) will require additional feeding and in organic farming this is often supplied in liquid form. Diluted urine can be useful, if applied with care with the addition of wood ash (to enhance potassium) and also liquid feed from composting leaves. However diluted urine should not be applied until the flowers have formed and the early small fruit is starting to grow. If too much nitrogen is given (such as with too much urine application), the leaves will grow abundantly with less fruit production. After fruiting has begun more nitrogen (from urine) and particularly potassium (from wood ash) can be applied for the best yields. Tomatoes do require a lot of attention and special treatment to do their best. For more information on growing tomatoes using recycled human excreta, look at the chapter on gardening techniques.


Growing tomatoes in bags and buckets

More examples of plants grown with the help of urine

Young mulberry cuttings once established respond well to a dose of 5:1 water and urine weekly (0.5 litres per plant). The same applies to the mint plant on the right growing in a 10 litre bucket.



Passion fruit also responds very well to the application of urine and water. In a 30 litre pot this passion fruit is fed with 1 litre of a 5:1 mix of water and urine weekly. The petrea tree is also fed a 5:1 mix of urine and water (10 litres every month).

Celery also responds well to a 5:1 mix of urine and water (0.5 litres per container weekly). This large radish was fed in the same way.

MAIZE

Urine can have a significant effect on maize growth. In the fields urine can be applied neat to soil before planting in beds. It can also be applied neat in hollows made near the growing plant. Neat urine applied to maize fields at the rate of 100mls per plant per week and then diluted with rain water, led to increases of cob weight between 28 and 39% compared to watered fed plants only in trials on the Marlborough vlei in Harare (See bibliography Ecological Sanitation in Zimbabwe vol. IV)

Maize trials on the fields using urine.

Growing maize in containers

Maize is rarely if ever grown in containers, but the effect of the growth of maize in containers when fed urine is stunning. Maize plants are hungry feeders and like a lot of nitrogen The application of a 3:1 mix of water and urine, once or twice or even three times a week on maize grown in 10 litre containers is particularly effective. For small scale maize or sweet corn production, this method may have application. It is also an effect way of demonstrating the effect of converting the nutrients held in urine into vegetative growth of valuable plants.

Left: The maize plant on the right is being fed with a 3:1 mix of water and urine (0.5 litres) three times per week. The maize on the left is irrigated with water only. The difference is striking. Right: Urine treatment also improves maize cob yield significantly. The total yield of cobs from maize planted in three 10 litre basins is shown. On the left the maize was fed 1750mls urine per plant over the 3.5 month growing period, resulting in a crop of 954 gms. A reduced crop resulted from reduced input of urine (middle). Maize plants on the right were irrigated with water. This is a very high rate of urine application, but one happily accepted by the maize plants in the containers which were irrigated frequently with water to keep the maize plants healthy.

Growing maize with the help of toilet compost and urine on poor sandy soils

Maize is the single most important crop in Southern and Eastern Africa – being the staple diet for hundreds of millions of people in the sub- region. And large numbers of these people live on poor sandy soils, which cannot support a good crop of maize without fertiliser, or adequate quantities of cow manure. For those living in the urban areas and peri-urban fringes, cow manure may be scarce and commercial fertiliser too expensive to buy. Yet millions of people eek out a living in these settlements by growing their own crops of maize and vegetables every year in back yard plots and gardens close to the home. It is a means of self survival in conditions which are often harsh and where malnutrition abounds. The simple question is then asked - can the use of toilet compost and urine, in combination, significantly increase the production of these backyard gardens, and thus make the effort worthwhile.

The work reported earlier in this chapter shows clearly how maize production can be enhanced considerably by the application of urine. Maize is a "greedy feeder" and requires considerable amounts of nitrogen to grow at its best and provide generous harvests. It also requires adequate amounts of phosphate in its early stages to enhance the growth of the root system and the young stem above ground. Normally, if commercial fertilizer is used a single maize plant is given at least 10gms of a mix of nitrogen, phosphorus and potassium in the ratio 1:2:1 (in Zimbabwe this fertilizer is known as Compound D). The elevated phosphorus content helps early root formation and shoot growth. At 4 weeks (or when the plant is at knee height) a further application of 10gms or more of ammonium nitrate is given. This is normally sufficient to carry the plant through its full vegetative growth. These two applications of "granular slow release" commercial fertilizer offer each plant between 4 and 5 gms of nitrogen, about the same as is found in one litre of urine produced by people who have a low protein diet - sadly the great majority who live in Zimbabwe. Very often an extra dose of ammonium nitrate is given when the young maize cob or cobs start to grow. This is thought to be an important application where bumper crops are required. It is generally known that the more nitrogen is applied the better the harvest. What is important is that the nutrients supplied first help the root and early shoot system, with the bulk of the nitrogen being applied to assist vegetative growth and cob formation during the life of the plant. So it helps if this application of nitrogen can be extended into the period of "grain filling" when the cobs themselves are growing. Grain filling normally starts about 10 weeks after the seed is planted. The cobs continue to gain in weight from 4 to 6 weeks after their formation. Good rains or adequate water supply are very important during this phase.

These requirements are well served by first planting the maize seed in a "plug" of toilet compost made in the soil. This compost is well aerated and contains humus – a requirement particularly useful for sandy soils. It also provides a supply of phosphorus and some nitrogen, suitable for the germination and early growth of the plant. Toilet compost also makes an excellent potting soil and is an ideal medium for the germination of seeds of many kinds. This compost is particularly valuable where local topsoil, like fine sandy soil, may not provide the ideal medium for germination. About 500 gms of toilet compost are applied per planting station. This is about one pea tin full.

A field trial in Epworth near Harare

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 experiment, the field was dug and levelled beforehand and on planting day hundreds of small holes were dug in lines and rows ready for planting. 125mls of urine (which had been collected in 20 litre plastic containers previously) was applied to each "planting station." This was followed by a 500gm plug of toilet compost. Two seeds were planted in the compost and covered over.


The field is prepared by digging and holes are made 30cms apart in rows 90cm apart. The 20 litre drum of collected urine is shaken up (to mix the phosphorus) and added to a 20 litre bucket. Date 5.11.2004


Using a dispenser, 125mls of urine is added to every hole

This is followed by one pea tin full (500gms) of toilet compost taken from the *Fossa alterna* or other composting toilet. Two seeds are then planted in the compost and pressed down and then covered with the topsoil. If seeds are in short supply then a single seed can be planted. Over 90% of registered maize seed will germinate. Another seed can be planted if a single seed does not germinate.

The seeds are pressed into the compost and covered with topsoil awaiting the rains

On the left the field site at Epworth showing the *Fossa alterna* from where the humus was taken. Picture on right taken 2nd December 2004 when the maize had started to grow.


If two seeds had germinated, which was normally the case, one was removed and planted elsewhere. Adding the second 125mls application of urine to the young plant.


Photos taken on 3rd January 2005. On the left photo the plants on the lower left were not treated with urine. Plants in mid picture and right had been treated. The difference is obvious. On the right photo, the lush growth of plants following urine treatment is clear to see.


Digging small hole near to plant step prior to urine application. On the right, the urine has been stored in the 20 litre plastic container. It is poured into a bucket and then dispensed with the small pill bottle dispenser next to each plant.

Applying the 125mls of urine in a hollow next to the plant. Best to cover over after application. 125mls are added weekly to each plant, the last 2 applications are added fortnightly to make a total of 1000mls for each plant. This is equivalent to around 5gms nitrogen.

17th January 2005, first signs of tassel (left) and cob (right).

This photo was taken 31st January 2005 at the time when the last of the urine was applied. In the treated area (right) the growth of maize has been good and cobs are already forming. On the left the untreated area shows smaller and paler plants with little cob formation.

Healthy lines of maize with healthy cobs growing in treated zone on 31st January 2005. On the right two cobs are growing, revealing that the urine application as per the schedule is adequate. On this day the final 125mls of urine was added making the total application one litre per plant. The first application was made at planting, the second to 6th application a week apart. The last two applications were spread a fortnight apart. This regime carries the application of urine nitrogen into the grain filling stage.

Final observations and cob measurement

In the current trial a small existing backyard maize field was chosen which also housed an ecological toilet ***(Fossa alterna*).** 200 maize were planted in 500gms of toilet compost 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 compost or 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

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

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 treatme nt had a significant effect on maize growth and cob size – with more consistently larger cobs. 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 application of 1 litre of urine per plant, applied in small lots (125mls) over the growth period, doubled the grain yield of maize growing on poor sandy soil compared to unfed plants.

15. Further plant trials using urine as a liquid feed

Now is the time to provide further evidence of the effect of urine treatment on plant growth and crop yield - particularly leafy green vegetables and the important crop of maize. There is an infinite variety of ways of applying urine to the soil - the dilution, frequency of application and volume applied are all variable. In the backyard vegetable garden the urine is best diluted with water and then applied periodically to the soil in which the plants are growing. Even when a particular dilution and frequency of application have been worked out, the response of plants to urine application may vary considerably - being influenced by several factors such soil type and its existing nutrient level and also the type and age of the plant itself.

Trial design

Since most of the plant trials described in this book have been undertaken in cement basins and plastic buckets, it is wise to explain the possible advantages and disadvantages of the container as an environment for growing vegetables and other crops. Take one example, for instance, where plants, say hungry feeders like maize, onion or even tomato, are grown in containers which hold a limited amount of soil available (ten litres). The soil in one container is fed water only and in the other container a water-urine mix. At first the soil filling both containers will be able to supply all the nutrient requirements for the early growth of the plants. Plants in both containers will grow equally. But as the plants mature, their demand for nutrients increases. Those plants fed with water only will slowly use up the available soil nutrients held within the container, and their growth may be retarded, depending on the nutrient level in the soil itself. The plants fed with water and urine will continue to grow healthily, using nutrients derived from the urine. For this reason the increased growth recorded in urine fed plants in these trials are the direct response to the nutrients available in the urine alone. Such growth is the result of an increased supply of nutrients only – urine has no influence on the physical properties of the soil.

There are some positive aspects to growing plants in containers. Those nutrients derived from the urine are dispersed and converted only in the soil held within the container itself. Thus the reaction can take place in a well defined volume of soil and not be dispersed and perhaps lost to the plant, as would be the case in fields or even vegetable beds where the soil depths are greater and excess watering or rain can drive the nutrients (particularly nitrogen) deeper into the soil. In Sweden urine is not applied to the fields during the main autumn rains, partly because of the fear that the nutrients will be lost as the rain soaks into the soil and makes its way down to the standing water table (Håkan Jönsson pers.comm.). There is a net movement of water down to much deeper levels in the soil. Thus soluble nutrients like nitrate may be lost to the topsoil during heavy rain. In Southern and Eastern Africa, maize is planted during the main rains, when water drains down through the topsoil and the "overburden" to top up the aquifer beneath. It is during heavy rains that there is a loss of nutrients from the topsoil to deeper lays. Nitrogen in particular is very soluble and easily flushed away during the rains. Thus the effect of nitrogen may be reduced or lost. Slow release commercial fertilisers in granular form assist by releasing their products slowly over time, but even in this case, the type of rainfall may influence the effect of the fertiliser on nutrient retention and uptake by the plants. Where nitrogen is released from urine, much of it may be flushed down below the root layer during heavy rains and the effect on maize growth will be less pronounced. Conversely if there is reduced rainfall and no artificial watering, the effect of urine treatment on plant growth can also be poor (Björn Vinnerås pers.comm.). Thus the use of basins has at least one advantage, that the use and uptake of urine may be more effective and the resulting uptake of nutrients greater. Also because the urine is applied quite frequently, any loss of nitrogen after flooding can be made up on the following application. By comparison, phosphorus binds better with the soil and is less easily flushed away during heavy rain (about 10% may be lost due to leaching). The salts of phosphorus derived from urine, calcium phosphate and magnesium ammonium phosphate ("struvite") are both good slow release fertilisers (Håkan Jönsson pers.comm.). Potassium is also fairly stable in the soil with about 10% loss due to leaching (Hopkins 1945).

Another factor is "pot binding," where the roots of plants growing in containers, being confined, have a negative influence on plant growth. This may be the case for the use of 10 litre cement basins and plastic buckets, where the root volume increases to occupy much of the space of the container. The roots of maize plants grown for 3 months in a 10 litre container occupy a great percentage of the volume of the container. And yet they appear to thrive well enough. The writer has grown maize 1.2 metres high in soil 100mm deep and produced maize cobs weighing 365 gms. The advantage is that once the crop has been harvested, the soil in the containers can be recycling through the compost heap and the roots sieved out. There can be constant replenishment of the soil held in containers– it is very adaptable method not dependent on the nature of local topsoil – which is invariably poor. When containers are emptied and the soil recycled, a huge array of roots can be seen in the soil. So much in fact that the roots bind the soil to form a plug. Once the crop has been harvested the plug of soil is removed, sieved and recycled ready for use in the next series of containers.

So there are advantages and disadvantages of growing vegetables and other food crops in containers. For experimental purposes they are ideal, since their environment can be standardised. The aim is to interpret the results for use in other environments. The writer has had much success in growing a wide variety of food crops in 10 litre cement basins, where 50 units can be made from a single 50 kg bag of cement together with river sand.

High levels of Nitrogen

Whilst vegetables require a lot of nitrogen, particularly for leafy growth, they also require phosphorus at an early stage to assist in root growth and early shoot formation and later potassium to help fruits form and mature. If there is too much nitrogen in the system, some of the other elements may not be able to act (Hill, 1981). Too much nitrogen can stress a plant and slow down its growth. If there is too much nitrogen about, the potassium, for instance, can get "locked up" - the transpiration system which becomes filled with chemical salts and only a fraction of salts like potassium gets through (Hill, 1981). Thus an excess of nitrogen may prevent other plant foods from working at their best. This is clearly very undesirable, particularly for plants that require potassium for fruiting - tomato is a good example. When there is much nitrogen the plant may direct nutrients to make more vegetative growth and leaves and use less to make the fruits. Also unless plants have plenty of humus in the soil they cannot take up the minerals even if the minerals are available. So it pays to introduce humus into the soil - as this helps the plant assimilate nutrients and also helps convert urea into nitrate which the plants can also use.

High levels of sodium chloride

Urine has a very high content of common salt (sodium chloride – NaCl). The daily output of urine (about 1.25 litres) contains about 7 gms chlorine and 5 gms sodium, combined to make sodium chloride, nearly as much as the 13 gms of nitrogen (mostly present as urea) and far more than the potassium and the phosphate. Excessive amounts of salt are known to be detrimental to plants (Håkan Jönsson pers. comm.) and can adversely affect the growth of plants. However, excess salt can be washed out by leaching with water. This may happen in the plant trials in containers – where a great deal of plain water is applied as well as the water/urine application.

Nutrient balance

We have already discussed in the previous chapter, that the ratio of nutrients contained in urine is not ideally balanced for vegetable or even maize production, particularly on phosphorus deficient soils, having a very high content of nitrogen in relation to phosphorus and potassium. Thus urine application at an early stage in plant life may actually slow down the growth of plants. This has been revealed in experiments in which the growth of seedling tomato, rape and spinach, fed urine continuously (at 3:1 and 5:1 applications) without further water dilution, grew more slowly than seedlings which were given water only. Thus, the initial nutrient need of the plants is best catered for by eco-humus and leaf compost.

This photo shows how the continuous application of urine can slow down the growth of seedlings. 3 rape and 3 spinach seedlings have been planted in each of the three lower sets of basins. The basin on the right has been watered with plain water only – the one on the left with a mix of 3:1 water and urine continuously. The one in the middle with a 5:1 water/urine mix continuously. The constant application of urine has slowed down plant growth, the greater the strength of the urine the more stunting effect. Plants are more tolerate of urine when they are more mature, and respond well to diluted applications of urine applied with plenty of intermediate watering with plain water.

Thus care is required on the application of urine, especially when the plants are young and require more phosphorus for their root and early shoot development. Whilst urine may not be the best plant food in terms of its nutrient balance, it is a great provider of nitrogen and has the unique advantage that it costs nothing and is freely available at all times to the gardener. Thus every possible advantage should be taken for the use of urine as a plant food.

PLANT GROWTH TRIALS WITH URINE

The following trials carried out on seedlings of lettuce, spinach, tomato, covo, and maize were conducted by planting the seedlings in either 10 litre buckets or basins and watering with plain water until the young plants were stable. Then some of the seedlings were watered with a urine water mix (normally 3 parts water and 1 part urine), three times per week and other control seedlings were irrigated with plain water only. This regime was followed for a specified number of days. At the end of the growth period, the plants were weighed and comparisons made between those fed with the urine/water mix and those irrigated with plain water only.

Lettuce - trials 1 & 2.

This trial was undertaken during August/September 2002.Three lettuce seedlings were planted in each of 4 X 10 litre buckets. The soil in two of the buckets was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), three times per week (U1 application) with all other irrigations with water only, over a 30 day period. The other two buckets were irrigated with water only. Since these trials were conducted in the winter with no rain, a lot of watering was necessary to keep the plants healthy. A second trial following the same procedure was also carried out over a 33 days period. The results are shown below.

Plant	Liquid plant food	frequency of application	weight harvested
Lettuce	3:1 water/urine	0.5 litres 3X per week	**500** gms (30 days)
Lettuce	water only	normal watering	**230** gms (30 days)
Lettuce	3:1 water/urine	0.5 litres 3X per week	**345** gms (33 days)
Lettuce	water only	normal watering	**120** gms (33 days)

Note 1: Lettuce 30 day trial. 3 plants were grown in each container, one being watered only the other being fed a 3.1 mix of water and urine 3 X per week (500mls per container). In this only the combined weight of 3 lettuce in each container was measured, not individual weights. 230 gms for water only fed lettuce and 500 gms for lettuce also fed the water/urine mix.

Note 2. Lettuce (33 day trial)

Plants irrigated with water only. Weights per plant :40, 40, 40. T = 120 gms, N = 3, M = 40, SD = 0.
Plants irrigated with water and a 3:1 water/urine mix. Volume of water/urine mix applied approx 160 mls per plant, 3 X per week. Weights per plant: 115, 100, 130. T = 345 gms, N = 3, M = 115gms, SD = 15.

The two samples are significantly different at the 95% level of confidence.

Thus between **two and three times** the yield of lettuce resulted from applying 0.5 litres of 3:1 water/urine mix, three times a week, interspersed with watering compared to lettuce which was irrigated with water only. This is a significant increase in yield, resulting from the application of about 0.5 litres of urine per plant over the growth period. This is just less than one third of the daily output of urine per person per day.

Photo of lettuce growing in soil irrigated with water and urine (3:1) on the right (500gms) compared to 230 gms on the left grown on soil irrigated with water only.

Rape

This trial was undertaken during December 2003.Three rape seedlings were planted in each of 6 X 10 litre cement basins. The soil in three of the basins was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), twice a week (Saturdays and Wednesdays) with all other irrigations with water only, over a 28 day period. The other three basins were irrigated with water only. The first application of urine took place on 3rd December 2003 and the crop was harvested on 28th December 2003. The results shown below indicate a five fold increase due to urine treatment.

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)

Individual plant weights. Plants irrigated with water only: 51, 4, 38, 12, 10, 6, 4, 5, 30. T = 160 gms, N = 9, M = 17.77gms. Plants irrigated with water and a 3:1 water/urine mix (approx 160 mls per plant), 2 X per week. Weights per plant: 160, 68, 79, 94, 119, 91, 81, 100, 30. T = 822 gms, N = 9, M = 91.33gms.

Photo on the left shows little effect of urine after 10 days (water application on left, urine application on right – 13th December.). After 28 days (31st December) the effect is noticeable (photo on right with water treatment below and urine treatment above - the basins are obscured).

Photo on left shows nutrient deficiency on water fed basin. The mauve colour is due to deficiency of phosphorus. On the left the total harvest of rape from water fed basins (left) and urine fed basins (right).

The experiment was continued for another 28 days during which all the basins were fed the same 3.1 mix of urine and water, twice a week. There was surprisingly little reaction in the hitherto untreated plants, whilst the previously urine fed plants continued to respond to the urine treatment. The results below show that the previously urine fed plants continued to yield more than the more recently urine fed plants also by a factor of about five times. Rape is a sensitive plant, and perhaps the lack of nutrients in the early stage of growth of water fed plants led to a poor development of the root system. Thus despite the later application of nutrients, the plants failed to respond.

Plant	Liquid plant food	frequency of application	weight harvested
Rape	3:1 water/urine	0.5 litres 2 X per week	108 gms (7 plants)
Rape	3:1 water/urine	0.5 litres 2 X per week	713 gms (8 plants)

Individual plant weights. Plants irrigated with water and a 3:1 water/urine mix for the first time: 6, 10, 8, 13, 12, 24, 35. T = 108 gms, N = 7, M = 15.4gms. Plants irrigated with water and a 3:1 water/urine mix (approx 160 mls per plant), 2 X per week for the second month. Weights per plant: 98, 38, 72, 30, 130, 125, 129, 91. T = 7138ms, N = 8, M = 89.12gms.

Rape plants after 8 weeks of urine treatment (upper row)

In being a sensitive plant, rape also reveals nutrient deficiencies more readily than the tougher spinach plant. Towards the end of the second month of urine treatment very obvious signs of deficiencies of both phosphorus and magnesium were revealed, despite the generous urine treatment, or perhaps because of it. Phosphorus deficiency shows up as a mauve colouring in the leaves, and magnesium deficiency as a yellowing of the leaves, whilst the leaf ribs remain green. They indicate that for rape at least, the urine treatment given (0.5li X 3:1 X 2 per week) was too high for long term application. This may have been caused by too much salt or potassium provided by the urine which adversely affects magnesium uptake. The lush growth caused by high nitrogen input may have later led to inadequate phosphorus being available for the plant from the urine provided. Phosphorus is the least available of the major plant nutrients in urine.

Closer view of nutrient deficiencies showing up in rape after 8 weeks of urine treatment. The mauve colouring ís due to phosphorus deficiency and the yellowing of the leaf with green leaf ribs is magnesium deficiency. Both may result from high applications of urine. The application of urine was subsequently reduced from 0.5li per basin of 3:1 twice per week to 0.5li per basin of 5:1 once per week

The conclusion to be drawn is that for rape the 3:1 treatment twice a week is too high for prolonged application, and this was subsequently reduced to a 5:1 treatment weekly for all plants.

Spinach (trial 1)

Spinach is a hardy, easily grown vegetable which is very popular in Africa and all over the world. It grows easily from seed, grows well in beds and basins and is very responsive to the use of urine. The plant, once established can be repeatedly reaped for several months. The main leaves are harvested leaving one or two of the youngest leaves on the plant to start a new regeneration. It is therefore a natural choice for plant trials using urine. This trial was undertaken during August/September 2002. Three spinach seedlings were planted in each of 2 X 10 litre buckets. The soil in one of the buckets was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), three times per week with all other irrigations with water only. The other bucket was irrigated with water only. The spinach was reaped after a 30 day growth period. The results are shown below. The urine/water application increased the harvest of spinach by over **six times**.

Plant	**Liquid plant food**	**frequency of application**	**weight harvested**
Spinach	3:1 water/urine	0.5 litres 3X per week	**350** gms (30 days)
Spinach	water only	normal watering	**52** gms (30 days)

Note: Spinach 30 day trial. 3 plants were grown in each container, one being irrigated with watered only, the other being fed a 3.1 mix of water and urine 3 X per week (500mls per container). Only the combined weight of the 3 spinach grown in each container was measured and not individual weights. 52 gms of spinach were measured in the container irrigated with water only. 350 gms of spinach were measured in the container irrigated with a 3:1 mix of water and urine and also water at other times.

On the left 52 gms of spinach produced in a bucket after 30 days of water treatment compared to 350 gms of spinach on the right in a bucket after water/urine treatment.

Spinach (trial 2.)

This trial was undertaken during November/December 2003. Three spinach seedlings were planted in each of 16 X 10 litre cement basins (29th November). The soil in eight of the basins was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), twice a week (Saturdays and Wednesdays) with all other irrigations with water only, over a 28 day period. The other eight basins were irrigated with water only. The first application of urine took place on 3rd December 2003 and the crop was harvested on 28th December 2003. The results shown below indicate a 3.4 fold increase due to urine treatment.

Plant	Liquid plant food	frequency of application	weight harvested
Spinach (22plants)	Water only	normal watering	741gms
Spinach (22plants)	3:1 water/urine	0.5li. 3:1 X 2 per week	2522gms (X 3.4)

Individual plant weights.
Plants irrigated with water only. Weights per plants: 4, 29, 69, 42, 21, 26, 31, 22, 40, 32, 15, 40, 24, 115, 2, 25, 42, 4, 51, 30, 40, 37. T = 741 gms, N = 22, M = 33.68gms.
Plants irrigated with water and a 3:1 water/urine mix (approx 160 mls per plant), 2 X per week. Weights per plants: 151 65, 80, 35, 28, 39, 138, 32, 236, 35, 69, 68, 42, 31, 110, 164, 195, 219, 106, 389, 250, 40. T = 2522gms, N = 22, M = 114.63gms.

Photos taken of the 16 basin spinach trial. Basins to the left of the green band are urine fed, those to the right water fed only. Photo on left taken on 3rd December 2003 on the first day of urine treatment. Photo on right taken on 31st December 2003, 28 days after first urine treatment. The effect of the urine treatment is very positive and very clear to see.

Plants were individually weighed on 31st December, 28 days after urine treatment began. On the right the total collected harvest of urine treated spinach on the left and water treated spinach on the right.

After cropping, the experiment was continued for another 28 days during which the original 8 urine fed basins continued to be fed urine at the same rate (0.5li of 3:1 X 2 per week). A further four basins which had so far not been treated urine were fed urine at the same rate of the others. The remaining 4 basins were initially fed two treatments of the water/urine mix and then covered with leaf mulch and fed with leaf compost liquor (0.5litres, twice a week). This was done to compare the influence of urine and leaf compost liquor application. All plants were watered to keep healthy at all other times. The results are shown below.

Plant	**Liquid plant food**	**Application rate**	**weight harvested**
Spinach (18plants)	3:1 water/urine (2nd month)	0.5li. 3:1 X 2 per wk	1917gms (18 plants)
Spinach (10 plants)	3:1 water/urine (1st month)	0.5li. 3:1 X 2 per wk	853gms (10 plants)
Spinach (22plants)	Water/urine X 2 + leaf liquor	0.5li. 2 X per wk	1312gms (11 plants)

Individual plant weights.
Plants irrigated with urine (2nd month). Weights per plants: 42, 227, 22, 67, 140, 148, 60, 35, 143, 41, 189, 118, 55, 163, 160, 140, 180, 41. T = 1917 gms, N = 18, M = 109.5gms.
Plants irrigated with urine (1st month). Weights per plants: 38, 63, 60, 40, 97, 153, 94, 95, 148, 65. T = 853gms, N = 10, M = 85.3gms.
Plants irrigated with urine (2 applications) + leaf compost liquor. Weights per plants: 163, 162, 63, 108, 123, 123, 39, 219, 130, 132, 50. T = 1312gms, N = 11, M = 119.27gms.

Discussion

Previously urine fed plants continued to produce a good harvest during the second 28 days period of urine treatment, with a slightly reduced mean weight per plant of 109.5gms compared to the original 114.63gms. The mean weight of plants fed urine over a 28 day period after 28 days of water treatment only was less at 85.3 gms per plant. Clearly with urine treatment, the best plant growth results when urine is applied as the plant is still maturing. However the best mean weight of plants resulted from a combination of urine treatment (2 applications) followed by a series of application of leaf compost liquor. Here the soil was covered with a thick layer of leaf mulch. The liquor fed plants were lighter green in colour and looked more succulent and healthy. By comparison the urine fed plants were darker and appeared more prone to insect attack. Perhaps the liquor fed plants received a better balance of nutrients and this led to an overall improvement in the general condition of the plant. Also the mulch may have contributed to plant growth, partly by supplying extra nutrients, partly by reducing weed growth (which was rampant in many of the urine fed basins) and partly by reducing water loss from the soil. Reduced leaf weight due to insect attack, which was more common in urine fed plants compared to liquor fed plants, would also have reduced the mean weight per plant.

However liquor fed plants showed some early signs of nitrogen deficiency, revealed by yellowing of basal leaves in some plants. Leaf liquor does not have the same nitrogen content as diluted urine. Clearly the application rate of the liquor was not adequate to keep up with the optimal growth of the spinach. An increased application of liquor would therefore serve the plants better.

Of interest here is the effect of combining. The combined application of diluted urine with leaf liquor appears to have been effective. It is possible that the liquor provides more of the minor nutrients and helps to increase phosphorus and potassium, whilst the urine provides nitrogen, the initial boost of only two applications being beneficial.

The conclusion to be drawn is that prolonged urine treatment, even for spinach, may be more effective with a lower dose (0.5li. of 5:1, once per week), since the reduced nitrogen in the overall urine/liquor application during the 28 days period appeared to increase the crop, not reduce it. The application of both leaf liquor (if available) and diluted urine appears to be the most favourable option, possibly with a single dose of diluted urine once per week with intermediate liquor applications. The other beneficial feature is the introduction of a leaf mulch to the basins in which plants are growing.


Left: heavily urine fed plants turn dark green but appear to be more susceptible to insect attack as shown. Right: in this trial the much lower dose of urine coupled with leaf liquor treatment produced lighter green and succulent leaves which were less attacked by insects.

The garden of 16 cement basins with spinach used in this trial on the day of the second harvesting. Compare to the days of first harvesting, above. The plants nearer the camera are larger in this case. The lower dose of urine combined with leaf compost liquor has been effective. On the right the three piles of spinach, on the left the liquor fed (11 plants), in the middle the plants fed initial 28 days of urine treatment (10 plants), on the right plants fed with urine during 56 days (18 plants)

On the left the pale yellow leaf of one of the liquor fed plants revealing slight lack of nitrogen. On the right the nitrogen deficiency on spinach (below) is compared to magnesium deficiency in rape (above).

Spinach trial 3. (adjusting the balance of nutrients in urine application)

Urine has a very high content of nitrogen in relation to the levels of both phosphorus and potassium. Phosphorus is valuable for root growth and the establishment of early shoots and potassium valuable for fruit formation and the overall health of the plant. So the less than ideal balanced nutrients available in urine may reduce the overall capacity of the plant to reach full growth and maximum health. This trial was undertaken by comparing the growth of plants on relatively poor soil irrigated with water with plants grown on the soil irrigated with a 3:1 mix of water and urine and also a special mix of 5:1 water and urine to which supplementary phosphorus (5 gms) was added. The volume of 3:1 mix and 5:1 + P mix was 0.5 litres per container, twice per week. All plants were placed in 10 litre cement basins. Thus the N/P ratio was changed in the second type of application with the proportion of nitrogen falling and phosphorus rising. The spinach were planted on 3^{rd} December 2003, with urine application starting on 12th December. Applications of either 3:1 (water and urine) or 5:1 water and urine supplemented with 5gms single super-phosphate fertiliser were applied twice per week for 4 weeks with harvesting taking place on 9^{th} Jan.2004, 4 weeks after the first urine application. All plants were irrigated with water to keep them healthy at all times.

Results (weight of individual plants in grams after 1st 28 day period)

Water fed plants (5 plants): (10, 10) (16, 9, 12). Total wt.= 57gms. **Mean wt =11.4gms**
Plants fed 3:1 water/urine 2 x per week. (9 plants): (40, 74, 32) (68, 43, 22) (62, 70, 47). Total weight = 458gms. **Mean wt = 50.88 gms**. **4.46 times water fed plants.**
Plants fed 5:1 water/urine with P. 2 X per week (9 plants): (103, 43, 88) (135, 58, 95) (145, 66, 59). Total wt. 792 gms. **Mean wt = 88.00 gms**. **7.71 times water fed plants.**

On the left a photo taken on 12th December just over a week after planting. The two basins on the extreme right are fed with water only. The 3 upper basins from the left were irrigated with a 5.1 mix of urine and water (250mls + 50 mls) with 5 gms phosphate added, twice per week. The whitish colour of the phosphate can be seen on the soil. The 3 lower basins from the left were irrigated with a 3:1 mix of urine and water (about 300mls) three times per week.

The same basins 4 weeks later. Note the considerable growth in all urine fed plants, compared to the water fed plants. The application of the 3:1 urine/water mix (twice per week) led to 4.4 fold increase in spinach yield. The application of a 5.1 urine/water mix with additional phosphorus led to a7.7 fold increase in spinach yield. This result reveals the importance of phosphorus at an early stage of plant growth and how it can influence the final yield. Even the greater quantity of nitrogen present in the 3:1 water/urine application did not lead to a greater crop yield even with this green vegetable. Unfortunately urine has a low proportion of phosphorus compared to nitrogen and the best effects of urine are felt when the levels of other nutrients are elevated in some way.

The cut spinach after 4 weeks of urine application. The plants fed water only are very small on this poor soil (lower left). The mean weight of the 9 plants fed a 3:1 water urine mix was about 50gms (lower right) compared to 88gms for plants fed a 5.1 water/urine mix with phosphorus added. The application of less nitrogen and more phosphorus had a very positive effect on crop yield

After cropping, the experiment was continued for a further 4 weeks in which the water fed and 3:1 urine fed plants were irrigated in the same way as the first 4 weeks. However the 5:1 application was modified with the 5g phosphorus being replaced with 5g wood ash to supply potassium. Thus 50mls urine was combined with 250mls water to which 5gms wood ash was added. This treatment, like the 3:1 treatment was carried out twice per week.

Once again, after a further 28 days of growth the 5:1 water/urine treatment with additions (ash) produced a higher yield than the 3:1 treatment. So once again, the greater quantity of nitrogen present in the 3:1 water/urine application did not lead to a larger crop yield even with this green vegetable. Urine has a low proportion of both phosphorus and potassium compared to nitrogen and the best effects of urine are felt when the levels of other nutrients are elevated in relation to nitrogen, as the experiment reveals. Diluting the nitrogen (urine) more, and adding supplementary nutrients like P and K with correspondingly higher yields resulting appears to reveal that urine is not a well balanced plant food and is best applied with additional nutrients being applied. However, even with no supplementary nutrients being added, the urine fed yield on green vegetables growing on containers is still considerably higher than vegetables fed water alone.

The results of the second crop harvested after a further 28 days of growth are shown below.

Results (weight of individual plants in grams after 2nd 28 day period)

Water fed plants (5 plants): (10, 8) (10, 10, 14). Total wt.= 52gms. **Mean wt =10.4gms**
Plants fed 3:1 water/urine 2 x per week. (7 plants): (80, 59) (57, 30) (61, 102, 92). Total weight = 481gms. **Mean wt = 68.71 gms**. **6.60 times water fed plants.**
Plants fed 5:1 water/urine with wood ash 2 X per week (9 plants): (39, 23, 80) (127, 65, 209) (150, 61). Total wt. 754 gms. **Mean wt = 94.25 gms**. **9.06 times water fed plants.**

The spinach plants just before cropping, 28 days after first cropping. The two basins on extreme right hand side have been water fed only. The upper three basins have been fed a 5:1 water/urine mix with wood ash added. The lower three basins have been fed a 3:1 water/urine mix only. Even although green vegetable growth like spinach relies heavily on nitrogen, the additional phosphorus and potassium from wood ash enhanced the growth.

The cut spinach after a further 4 weeks of urine application. The plants fed water only are very small on this poor soil (mean wt 10.4 gms). The mean weight of the 7 plants fed a 3:1 water urine mix was about 68 gms compared to 94 gms for plants fed a 5.1 water/urine mix with wood ash added. The application of less nitrogen and more phosphorus followed by more potassium (in wood ash) had a very positive effect on crop yield

Discussion

This is an interesting result since it reveals that the final weight of even green vegetables, which are nitrogen hungry, is not entirely due to the quantity of nitrogen supplied, but is also considerably influenced by the level of phosphorus and also potassium. Whilst the application of a 3:1 mix of water and urine led to a 4.4 fold increase of the weight of spinach, the additional measure of phosphorus with reduced nitrogen led to a 7.7 fold increase in the harvest compared to water fed plants. It is assumed this is a direct relation to the enhanced root growth that would have resulted from extra phosphorus application. All plants benefit from the early healthy development of the root system, and this seems to have been revealed here. If the soils are deficient in phosphorus, which most soils in this part of Africa are, then the additional application of phosphorus is very beneficial. Perhaps this is why nearly all compound fertilisers sold in Zimbabwe have a higher proportion of phosphorus compared to other major nutrients. When the ratio of nitrogen to phosphorus is too high, the increased needs of the growing vegetative plants above ground cannot be fully met by the less developed root system, which in itself leads to a reduced overall crop.

The second 28 day harvest in which potassium (supplied by wood ash) was elevated also increased the yield but not to the same extent as the first 28 day harvest when phosphorus was elevated. The increase of mean plant weight by applying less nitrogen and more phosphorus (5:1 + P) compared to the standard water urine mix (3.1) was 1.72. This compares to a 1.37 fold increase of mean plant weight by applying less nitrogen and more potassium (5:1 + K) compared to the standard water urine mix (3.1). It is not known whether the increased growth during the second 28 day period is due to the additional potassium added or to the larger root system that may have developed during the first 28 days. In any event, the combined use of both additional phosphorus and potassium (with wood ash) was very beneficial to plant growth as shown below. The overall increase in harvest by applying both P and K was 1.64 compared to the 3:1 application only.

Total 56 day crop (2 croppings)

	Water only	3:1	5:1 with P and K
1st 28 day harvest	57 gms	458 gms	792 gms (with P)
2nd 28 day harvest	52 gms	458 gms	754 gms (with K)
TOTAL	**109 gms**	**939 gms (X 8.6)**	**1546gms (X 14.18)**

Interestingly the second harvest for both types of urine application was little changed from the first harvest. However the increased harvest due to diluted urine alone was very significant well worth the effort. This trial was performed on very poor topsoil, when increased harvests are greater compared to plants grown on soil containing more nutrients. Also the die off of plants was less, 5/6 for water fed plants, 7/9 for 3:1 water/urine fed plants and 8/9 for 5:1 water/urine fed plants.

In ascertaining the best method of applying urine, it must be accepted that it does not have the ideal ratio of major plant nutrients. It is mainly a supplier of nitrogen with some potassium and phosphorus. Any method of raising the level of phosphorus in relation to nitrogen will improve the crop. Similarly with the uptake of potassium, if the nitrogen content is too high, potassium uptake by the plant will be reduced, leading to poorer yields of fruit and poorer health of the plant overall.

In this case the percentage of phosphorus was increased artificially by adding chemical fertiliser. Other methods involve sedimenting out the phosphorus and using the lower half of the mix which has a higher proportion of phosphorus in relation to nitrogen. Potassium levels can be increased (as in this case) by the addition of wood ash to the soil. Also comfrey has a high proportion of potassium and can be added as a mulch or a liquid fed to potassium hungry plants like tomato, onion, potato and beans. Alternatively the use of compost or humus from the ***Fossa alterna*** can be used to build up the phosphorus levels of soils which are deficient in this important mineral.

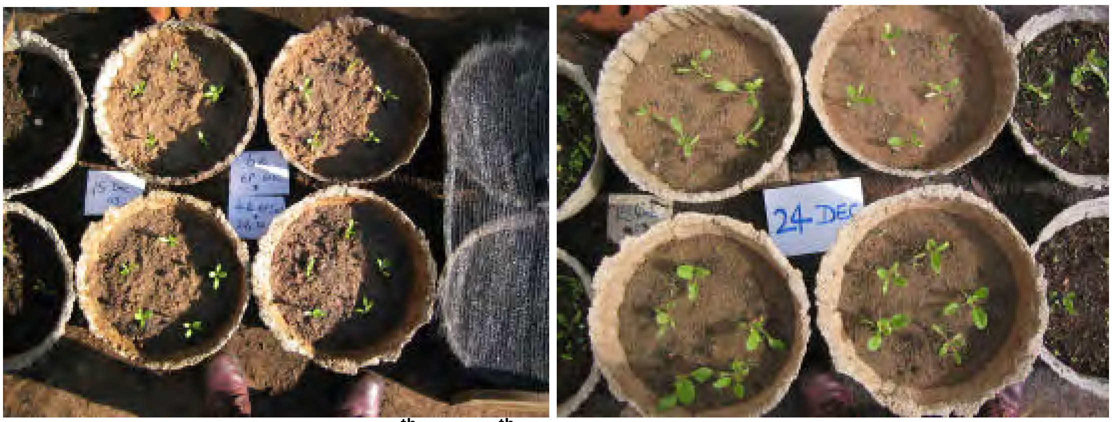
This experiment is also noteworthy in its implications for the growth of tomato, which responds very positively to the various primary plants nutrients. In particular a good supply of potassium is essential for a meaningful fruit crop, and too much nitrogen, whilst boosting leaf growth, will not induce a good harvest. As discussed later, the application of urine alone to tomatoes is not ideal.

Spinach trial 4. (effect on urine and *Fossa alterna* treatment on very poor soils).

This simple yet valuable experiment was conducted during the December 2003/January 2004 period. Four 10 litre basins were taken. Two were filled with a very poor sandy soil derived from the Epworth peri-urban settlement. The third and fourth were filled with a mix of 2 parts Epworth soil and one part ***Fossa alterna*** humus. By doing this some humus and nutrients were added to the poor sandy Epworth soil.

Five young spinach plants were added to each basin and kept watered. After 2 weeks 400mls of a water/urine mix (3:1) were added to two of the basins twice a week (one with Epworth soil and one with the mix of Epworth soil and ***Fossa alterna*** humus). This treatment was continued, twice a week for 28 days. On the 28th day the weight of each surviving plant was measured.

Results	Treatment	no.of plants	total weight (gms)	mean weight
Soil type				
Epworth	Water	4	6 (2, 1, 1, 2)	1.5gms
Epworth	Urine	3	33 (13, 10, 10)	11.00 gms
Epworth/FA	Water	5	34 (3, 9, 9, 10, 3)	6.8 gms
Epworth/FA	Urine	5	120 (11, 28, 10, 32, 39)	24 gms



Photos taken of the four basins on 15th and 24th December before urine treatment. The upper basins in both cases are plain sandy soil from Epworth, the lower basins are a mix of Epworth soil and *Fossa alterna* humus. The increase of spinach growth can already be seen in the lower basins. Urine treatment on two of the basins started on 31st December 2003.

The same basins photographed during at the termination of the experiment, 9 days and 28 days after urine application to the two lower basins in each case. In each photo the plain Epworth soil is on the right hand side and the mix of soils on the left hand side. The photos reveal the obvious result. Plants grow best when a combination of humus and urine is used.

Discussion

The experiment reveals that growth of even a hardy plant like spinach is very poor on the naturally occurring poor sandy soils of Epworth. 4 of the 5 plants survived with a mean weight of only 1.5gms. This must be compared to a mean weight of over 100gms per plant in similarly urine treated spinach in basins filled with better soil. The effect of mixing in ***Fossa alterna*** humus (ratio 2 soil to 1 humus) increased the mean weight of plants by about 4 times. The effect of adding diluted urine increased the mean weight of plants by about 7 times, although the survival of urine fed plants on plain soil was less. The greatest increase in plant growth (24 times) was recorded when both humus and urine were applied together, when the mean weight of plants after a 28 days period was 24 gms. This is still less than a quarter of what might be expected from urine treated spinach plants growing on better soil in basins.

These figures reveal the great challenge of improving vegetable production on very poor marginal sandy soils which are common throughout Southern Africa. It is clear that much greater increases in growth results from mixing very poor soils with ***Fossa alterna*** humus in equal proportions. In experiments carried out in 2002, spinach grown on a 50/50 mix of Epworth and ***Fossa alterna*** soil had a mean weight of 91gms compared to plants grown on plain Epworth soil (12 gms), an increase of 7.5 times. In another experiment a ten fold increase was recorded. The increased proportion of humus (50/50) clearly helped improve production in both cases. Clearly for very poor soils, ***Fossa alterna*** humus should be added in equal proportions to the sandy soil. Such increased production could be enhanced further by adding urine diluted with water. A weekly application of 5:1 would no doubt be very valuable. The slightly lower concentration of urine (5:1) compared to the 3:1 used in this trial would also increase survival rates.

The experiment reveals that urine alone is not effective at increasing vegetable production on poor sandy soils. A content of humus is essential for the effective use of urine on such soils. Whether this humus comes from the ***Fossa alterna*** or other sources is perhaps not important. Leave or garden compost would help and also mixing with more fertile soils or manure from elsewhere. The nitrogen in urine only becomes available to plants once it is converted by nitrifying bacteria present in the soil. One presumes that such beneficial bacteria is not present to any extent in these poor sandy soils.

Spinach (other trials)

Spinach, like rape and covo and various other green vegetables responds very well to urine treatment. It is a natural choice for plant trials involving urine treatment.

Two 10 litre basins planted with spinach. Soil in the left basin has been irrigated with a mix of 3:1 water/urine mix three times per week – the basin on the right just with water. The difference is very clear. Up to 2kg spinach can be reaped from a basin per harvest. Spinach can be harvested several times.

Vigorous growth of both rape and spinach in 10 litre cement basins. Both were irrigated with a 3:1 water/urine mix on the mornings of Monday, Wednesday and Saturday with all other irrigations just plain water. The photograph speaks for itself

This application of urine to spinach is a particularly successful one and many basins of spinach were enhanced in this simple way. Spinach, like covo can be cropped several times from the same plant. Like all the vegetables, spinach is also enhanced by the application of a 3:1 water/urine application even once per week – possibly a more practical way of applying it. The spinach in this trial was cropped after only 30 days growth, when the plants were still growing. Croppings of over 2kgs of spinach fed in the same way with urine have been made from 10 litre basins. Spinach is a very vigorously growing plant and responds well to the urine treatment.

Spinach, rape and tomato have been planted in these basins. On the left the plants are irrigated with a 3:1 water/urine mix and on the right with a fermented urine/comfrey mix. In both cases the growth is vigorous.

Covo. Trial. 1

Covo is a tasty and very popular vegetable, commonly grown in countless thousands of backyards in Zimbabwe. It is hardy and tolerates drought conditions better than most other leafy vegetables and is also more tolerant of low nutrient levels in the soil. Perhaps that it is why it is so popular as a vegetable grown on marginal soils. The leaves can be harvested for up to 2 years from the sturdy stem and new plants can be grown from cuttings.

In the trial, three covo seedlings were planted in each of two buckets of soil on 10th October, 2002. One bucket was fed with urine (0.5 litres 3:1 water/urine, 3 times per week), the other bucket being irrigated with water only. Two crops were harvested at monthly intervals. The total production of covo over the 2 month period was **153 gms** for water treated soil and **428 gms** for the urine fed plants, nearly **a three fold increase**. No individual plants were measured.

Covo. Trial. 2

This trial was conducted in 4 X 10 litre cement basins with three covo seedlings being planted in each on 11th October 2002. Two of the basins of covo were irrigated with water only and another with the U 1 urine treatment (0.5 litres 3:1 water/urine - 3 times per week for a ten litre basin holding 3 plants). Urine treatment started on 20th October. The fourth basin was fed with the U2 treatment (0.5 litres 3:1 water/urine – once per week for a ten litre basin holding 3 plants). All other irrigation was with water only to keep the plants turgid. The covo was cropped and weighed from each basin on 14th November, 13th December 2002 and 3rd January 2003. The total cropped weight of covo is given below:

Total weight of covo leaves cropped (11th October 2002 - 3rd January 2003)

Container	Yield gms
Basin 1 (water)	**134 gms**
Basin 2 (water)	**137 gms**
Basin 3 (U1 urine treatment)	**545 gms**
Basin 4 (U2 urine treatment)	**204 gms**

Notes With the Covo trial this same water/urine regine was fed 3 covo in a basin for about 8 weeks. The Covo was cropped three times, but on the first cropping only the combined weight of the 3 plants was recorded (127gms). Further crops of 108gms, 25gms and 25 gms were recorded on 3rd December and 148gms, 90 gms ands 22 gms were recorded on 13th December. Making a total of 545gms cropped for the 3 plants (181.6 gms per plant over the 8 week period).

The same recording pattern took place with the water fed plants. In this case 2 basins of 3 plants were watered and measured. The combined weight of plant reaped from one basin was 55 gms on the first weighing and 53 gms for the second basin. After this date individual plants were measured. On the 3rd December 12gms, 10 gms and 5 gms were reaped from one basin and 9 gms, 10 gms and 8 gms recorded from the second basin. On the 13th December 20 gms plus 24 gms plus 8 gms was reaped from the first basin and 15gms, 12 gms and 30 gms was reaped from the second basin.

So the total weight of covo cropped from the **3** urine and water fed plants was 545 gms (mean wt per plant 181.6gms. The total weight of covo cropped from the **6** water fed plants over the same period was 271 gms (mean wt per plant 45.16 gms). The average of the water fed plants over the period is 134 + 137 Div. 2 = 135gms). Thus the crop was increased by a factor of 4 times as a result of the water/urine treatment.

Significance of difference of crop of individually weighed covo.

Water Treated. 12, 10, 5, 9, 10, 20, 24, 8, 15, 12, 30. T = 163, N = 12, M = 13.58, SD = 7.44.
Urine treated: 108, 25, 25, 148, 90, 22. T = 418 gms, N = 6, M = 69.66, SD = 53.44.
The two samples are significantly different at the 95% level of confidence.

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Leaf growth in covo after a month of growth (just before second reaping). Picture shows basin with urine (U1) treatment (260 gms) and basin with water treatment only (57gms).

These results confirm that the stronger urine U1 application (3:1 water/urine X 3 per week) produced a better yield than the weaker U2 application (3:1 water/urine X 1 per week) and four times the yield of the water fed plants. The covo were able to cope with this urine dose, provided that normal watering was maintained at all other times to keep the plants turgid. However it is possible that the level of salt and nitrogen could build up to high levels in the soil held in small basins and restrict the growth over prolonged periods, i.e. several years. In practice the most efficient use of the urine was in the U1 treatment as shown below

Feed	**Weeks**	**Total urine/plant**	**Wt of covo**	**Increase**	**Mls urine/gm**	**ml/gm increase**
Water	10	none	**135.5gms**	-	-	-
U1	10	1250 mls	**545gms**	409.5	2.29 ml/gm	3.1
U2	10	400 mls	**204 gms**	68.5	1.96 ml/gm	5,8

There are various ways of looking at this result. By a small margin the U2 treatment was a more efficient way of using the urine. 1.96 litres were required to produce one gram of plant growth in the U2 treatment compared to 2.29 litres with the U1 treatment. But if one considers the increase in weight over and above the weight of water fed plants, then the U1 treatment was a more efficient way of using the urine.3.1 ml were required to gain one gram of plant growth above the water fed plants in the U1 treatment compared to 5.8 ml with the U2 treatment. In practice, an intermediate application of 0.5 litres of 3:1 water/urine applied twice a week (Wednesday and Saturday) on the soil with other daily applications of water being given may be effective and more practical.

Excellent crops of covo growing on 10 litre cement basins. Two plants are growing in the soil of each basin. The soil is actually a 50/50 mix of leaf mould and compost derived from organic kitchen waste, soil, and dog manure. Urine is applied twice a week as a 3:1 water/urine mi. 0.5 litres are applied with all other irrigation being plain water only. Grey water from a shower and wash basin is also applied. Self seeded tomato plants are also growing in the basins from seed found in the composted kitchen scraps.

Tomato

In this trial three tomato plants were grown in each of nine 10 litre buckets (total 27 plants) in garden topsoil. For the first month the plants were irrigated with water only to become established. For the next 4 months three buckets of tomato continued with the water treatment only. A further three buckets were watered with an application of 0.5 litres of water and urine (3:1 mix), 3 times per week (U1). The third series of buckets was fertilised with a urine/comfrey liquor containing a 5:1 mix of urine and water and fermented comfrey, also 0.5 litres per bucket of three plants, three times per week. The routine application of water was continued on all buckets at all other times to keep the plants healthy.

Less than one week after the application of the 3:1 water/urine mix the tomato leaves changed to a darker green colour and the growth of the plants was increased with leaves becoming far more fleshy and more numerous. The plants had more bulk - more stems, more leaves and potentially more fruits. This also took place with the 5:1 water/urine/comfrey application, but with leaves not so dark green in colour, revealing the lower input of nitrogen.

Yields of tomato over 4 month period

Plant	Liquid plant food	frequency of application	weight harvested
Tomato	water only	normal watering	**1680**gms (4 months)
Tomato	3:1 water/urine	0.5 litres, 3 X per week	**6084** gms (4 months)
Tomato	5:1 water/urine/comfrey	0.5 litres, 3 X per week	**6230** gms (4 months)

For the water fed plants, 41 tomatoes with a combined weight of **1680** gms were reaped (mean **40.97** gms) during the 4 month life of the plants. For the urine and water fed plants, 196 tomatoes with a combined weight of **6084** gms were reaped (mean **31.04** gms) during the 4 month life of the plants. Thus the total weight of tomatoes reaped from the urine fed plants was over three times the water fed plants, but the mean weight of each tomato was less. Thus the urine fed plants produced a higher number of smaller tomatoes. This may have been due to the higher proportion of nitrogen supplied by the urine which reduces potassium input which induces better fruit growth. The experiment lasted about 4 months. The first fruits were harvested on 23rd September 2003, with final fruits harvested early November.

Under the conditions of the trial, these results show a yield for tomatoes fed with the 3:1 water urine over **3.5 times greater** than similar tomatoes fed with water only. However the urine/water comfrey concoction did not provide yields much above the urine water mix.

Comments

These results do show that under the conditions of the trial, the applications of the 3:1 water urine mix, three times per week, resulted in a three fold increase in tomato production, although this larger harvest consisted of a larger number of smaller tomatoes. Nutrient levels in the soil picked up quickly after water/urine application and within one week the plants began to get larger and greener. An increase in fruit production followed. In fact all the tomatoes in the buckets which were fed water only used up the nutrients available in the buckets - they produced their fruits early and were also the first to die off – hallmarks of stressed plants. By comparison high levels of nitrogen fom the water/urine feed were maintained in the other buckets. Tomatoes fed in this way produced much leaf growth and also small fruit for a longer period. When plants like tomatoes are stressed they produce their fruits at a much earlier stage and less of them. Thus it is very probable that the tomatoes in the buckets fed with water only were responding to a stress situation brought on by a lack of nutrients, whereas those in the urine fed buckets were stressed by high levels of nitrogen.

The very poor yield of around 6 kg tomatoes from 9 plants (for urine/water and comfrey/urine liquor) is far below what can be expected from well fed tomatoes, and was most probably due to a combination of limiting factors. The soil used did not contain much humus, and it is certain that all tomatoes were stressed due to overcrowding. Also the high nitrogen regime in relation to the level of other nutrients will have reduced the full fruit forming potential of the plants. Tomatoes respond well to an initial boost of phosphate to help root growth and then subsequently enough nitrogen to boost vegetative growth, but also require potassium in generous quantities to produce the best fruit development. Urine, whilst high in nitrogen has much lower levels of potassium and even lower levels of phosphate and is certainly an unsuitable single plant food for the production of healthy tomatoes. A higher yield would have resulted from planting a single tomato in each bucket containing a more fertile, humus like living soil, with more potassium being made available.

The buckets on the right contain tomatoes irrigated with water only. Those on the left are being given the urine treatment.

Studies in Mexico with urine treatment of tomatoes also revealed that it was not the ideal plant food when used by itself, and after initially adding other chemical to urine to offset the deficiencies in phosphorus and potassium, chose to use the red worm (*Eisenia foetida*) to make fertile humus from kitchen waste in which the plants grew, which was high in available phosphorus and potassium. The urine, fermented by the addition of humus, was used as a liquid feed for tomatoes planted in a layer of enriched humus placed over a bucket of leaves - a method which produced excellent yields. Thus, where the soil is poor, compost or eco- humus is needed for soil improvement prior to the additional application of urine.

The tomato trial in particular reveals that whilst the application of urine can have a beneficial effect, plant health and an increase in crop yield depends largely on the plants growing in a healthy living soil, which contains a well balanced mix of nutrients. Indeed all these various trials reveal that the first priority should be to use soil which is fertile with compost mixed in to improve the content of humus and living organisms. Such compost already contains good quantities of phosphorus and potassium from the decay of vegetable matter. Tomatoes, onion, potatoes and beans all require a generous supply of potassium, as well as other nutrients. The high proportion of nitrogen in relation to other nutrients present in the urine, may prevent the plant from absorbing adequate amounts of potassium which it requires for the best fruiting and also for the overall health and vitality of the plants. A humus-like soil helps to balance the overall nutrients available to plants and this is particularly important when urine is added. Humus derived from ***Skyloo*** jars (see earlier) is a particularly good medium for growing tomatoes. It has a high content of humus and is full of living organisms. It also has high levels of phosphorus and potassium (the potash coming in part from the ash applied during the processing of the faeces). Tomato plants often spring spontaneously from these jars of humus and if well watered produce a good harvest. The application of a water urine mix (5:1 or 3:1) once a week, will help such well established plants along.

Plant trials with urine – summary for vegetables

The plants trials were performed on a variety of vegetables using urine diluted with water at a ratio of three parts water to one of urine as a liquid feed. Seedlings were planted in containers, either 10 litre buckets or10 litre cement basins and irrigated with water first. Fast growing vegetables like lettuce, spinach, covo and rape were irrigated with water first for 1 – 2 weeks before urine application after transplant and tomatoes were watered for a period of one month before urine application. Thereafter 0.5 litres of a 3:1 water/urine mix was applied to the buckets or basins on each urine application, this being the volume that the 10 litres of soil could absorb, interspersed with regular watering at other times to keep the plants healthy.

Summary of plant trials with urine for various vegetables & tomatoes

Plant and container	Urine/water application	Duration of growth	yield
Lettuce (10 litre bucket)	water only	30 days	230 gms
Lettuce (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	30 days	500 gms **(2 fold increase)**
Lettuce (10 litre bucket)	water only	33 days	120 gms
Lettuce (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	33 days	345 gms **(2.8 fold increase)**
Spinach (10 litre bucket)	water only	30 days	52 gms
Spinach (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	30 days	350 gms **(6 fold increase)**
Spinach (8 X 10 litre basins)	water only 22plants	28 days	741gms
Spinach (8 X 10 litre basins)	3:1 urine. 0.5 li X 2 per week for22 plants	28 days	2522 gms **(3.4 fold increase)**
Rape (3 X 10 litre basins)	water only 9plants	28 days	160gms
Rape (3X 10 litre basins)	3:1 urine. 0.5 li X 2 per week for 9 plants	28 days	822 gms **(5 fold increase)**
Covo (10 litre basin)	water only	8 weeks	135.5gms
Covo (10 litre basin)	3:1 urine. 0.5 li X 1 per week for 3 plants	8 weeks	204 gms **(1.5 fold increase)**
Covo (10 litre basin)	3:1 urine. 0.5 li X 3 per week for 3 plants	8 weeks	545 gms **(4 fold increase)**
Tomato (10 litre bucket)	water only	4 months	1680 gms (9 plants)
Tomato (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	4 months	6084 gms (9 plants) **) (3.6 foldincrease)**

Maize trials with urine treatment

Maize is by far the most important single plant species in Zimbabwe, and possibly throughout Africa. It provides the staple food for countless millions of people throughout the continent. Apart from where it is produced on commercial farms, it is usually planted in very marginal areas with poor soil. Manure can be used to enrich the soil - and also commercial inorganic fertiliser. But most rural and urban folk are not favoured with the ownership of cattle or the money to buy commercial fertiliser. Can Ecological Sanitation help? The results so far attained show that eco-humus alone, in economic amounts, does not hold sufficient nutrients to sustain many maize plants to full development. Urine was tried.

The soil on which maize is traditionally grown is normally fertilised either with cow manure or commercial fertiliser or a combination of both. With the commercial fertilizers the application is undertaken in two phases. The first application of the fertiliser has more phosphorus than nitrogen (the NPK ratio being 1:2:1). About 10 gms (a tablespoonful) are applied either to the seed as it is planted or near to the young plant after germination. Some farmers use double this amount. This sustains the growth of the maize plant for its first 4 – 8 weeks when a further application of ammonium nitrate (also 10 – 20 gms) is applied as a top dressing for each plant. If ammonium nitrate (up to 34% nitrogen) is not available a fertiliser with a high nitrogen content is used. This is a very standardised and well tested method of applying fertiliser to maize. Plants fertilised in this way look healthier, the leaves are more numerous, larger and greener and the resulting cobs certainly larger or also the number of cobs will be greater. More phosphorus than nitrogen is applied in the first phase of growth to assist in full root development. Subsequently the application of nitrogen takes over as the main nutrient required.

Most naturally occurring top soils in Zimbabwe require fertilisation if a good crop of maize is to be obtained, but cattle manure is not available for most people and nearly all those living in the urban and peri-urban areas. It should be noted that a huge amount of maize is grown traditionally in the cities and towns in both urban and peri-urban areas as well as in the farming and communal areas. Commercial fertiliser, is the obvious choice for soil fertilisation, but has become scarce in Zimbabwe (January 2003) and also prohibitively expensive. A hectare of maize may contain at least 30 000 plants, each requiring 10 gms of 1:2:1 (compound D or equivalent) and 10 gms of ammonium nitrate (or equivalent). Thus approximately 300 kg of fertiliser of both types would be required per hectare. The cost of this fertiliser, applied at this rate is high. A bag of 5 kg NPK 1:2:1 may cost up to Z$1700 and ammonium nitrate Z$1300 per 5 kg. This is a total of about Z$3000 (2002) which is enough to fertilise only 500 plants. For most rural and urban folk, this is an realistic price to pay.

The yield of maize is not only reliant on adequate fertilisation. Fields of maize require constant weeding to reduce competition for the valuable nutrients held by the soil. Also the time of planting is crucial. In Zimbabwe, the seeds should be planted by mid November so that the plants can grow during the wettest and hottest part of the year. If the planting day is delayed crop yields will fall. Also the pattern of rainfall is important. Late rains result in slow initial growth and wilting. Poor rains cause immense harm due to wilting. Very heavy rains cause leaching and loss of the nutrients held in the fertiliser. Because of the great variety of soils, nation wide – the recommended application of fertilizer does vary. The nation is reliant on a good maize crop, like no other plant.

Experimental design

A series of experiments were undertaken to test the effect of urine on the growth of maize plants and the yield of cobs. These initial trials were undertaken in containers - 10 litre basins and buckets. Further trials were also undertaken in shallow (plastic lined) back yard trenches and also in the open field. Seed maize was planted in seed trays and transplanted into buckets and basins with different soils and varying urine treatment. After periods ranging from 2.5 to 3.5 months the maize cobs were harvested and weighed. The basic aim was to establish what concentration and amount of urine could be used to sustain a meaningful growth throughout the plants life and one that would give the best yield of cobs. The efficiency of use of the urine was also tested. Urine has a high concentration of nitrogen and much less phosphorus and potassium. Thus in using urine as a source of nutrients, the balance of the main nutrients was not ideal. It is possible that too strong a concentration of nitrogen at an early stage may retard root growth, and thus hinder maximum plant growth. But after the initial phase, urine, with its high concentration of nitrogen is an ideal source of nutrients for maize.

For the maize trials the urine was diluted in the range 3:1, 5:1 and 10:1 with water. The plants were fed with urine either 3 times per week with the 3:1 mix (U1 application), once per week with the 3:1 application (U2), once a week with the 5:1 application (U3), once a week with the 10:1 application (U4) or with water only. Plants being fed the water/urine mix were also watered regularly at all other times to keep the plants healthy and turgid. After a specified growing period, the crop was harvested and weighed. A chart showing these various trials are given below. All watering was by hand - using a watering can – the old and reliable method.

Urine has a pronounced effect on maize, especially when grown in containers. In the trials, maize plants were grown in 10 litre cement containers and fed with varying amounts of urine. In this case the plant on the right is being fed with a 3:1 mix of water and urine (0.5 litres) three times per week. The maize on the left is irrigated with water only. The difference is striking.

Results of maize trials

A detailed account of the 16 maize trials that were conducted has been written in *Ecological Sanitation in Zimbabwe (Vol. IV).* These are complex and a detailed account is unnecessary in this book. A summary of the results and main findings is provided below.

Plant trials with urine for maize – summary of M8 and M14 trials

Plant and trial no.	Liquid application	Duration of trial	Mean cob weight
Maize (M8 trial) (10 litre basins)	Water only	3.25 months	21 gms (mean 3 cobs)
Maize (M8 trial) (10 litre basins)	3:1 urine. 0.5 li X 1 per week for 3 plants (U2)	3.25 months	135 gms (mean 3 cobs) **(6.4 fold increase)**
Maize (M8 trial) (10 litre basins)	3:1 urine. 0.5 li X 3 per week for 3 plants (U1)	3.25 months	318 gms (mean 3 cobs) **(15 fold increase)**
Maize (M14 trial) (10 litre basins)	Water only	3 months	6 gms (mean 9 cobs)
Maize (M14 trial) (10 litre basins)	10:1 urine. 0.5 li X 1 per week for 3 plants (U4)	3 months	62 gms (mean 8 cobs) **(10 fold increase)**
Maize (M14 trial) (10 litre basins)	5:1 urine. 0.5 li X 1 per week for 3 plants (U3)	3 months	138gms(mean 16 cobs) **(23 fold increase)**
Maize (M14 trial) (10 litre basins)	3:1 urine. 0.5 li X 1 per week for 3 plants (U2)	3 months	169gms(mean 18 cobs) **(28 fold increase)**
Maize (M14 trial) (10 litre basins)	3:1 urine. 0.5 li X 3 per week for 3 plants (U1)	3 months	211gms(mean 19 cobs) **(35 fold increase)**

Weights for M8 trial

Cob weight for water only (35, 17, 11g)T =63 N = 3 M = 21g, SD = 12.49
Cob wt for U2 urine treatment (170, 115, 121)T = 406, N = 3, M =135g, SD = 30.17
Cob wt for U1 treatment (290, 308, 356) T =954, N = 3, M = 318g, SD = 34.11

Weights for M14 trial

Water treated. 31,5,2/5,2,2/ 2,3,2. T = 54, N = 9, M = 6gms, SD = 9.46
U4 treated. 92,73,53/75,22/,60,81,40 T = 486, N =8, M = 62gms, SD= 23.05
U3 treated. 133,200,139/121,98, 212/225,150/90,140,40/212,155/132,125,38. T =2211, N = 16, M = 138g.SD = 55.94
U2 treated.205,162,132/122,175,225/126,197,211/155,208,150/160,122,133/218,172,180.T = 3053, N = 18, M = 169gms, SD = 34.87
U1 treated. 332,221,55/210,250,132/330,278,130/230,298,50/247,280,238/252,290,100,91. T = 4014g, N = 19, M = 211gms.SD = 90.47

In all cases the samples are significantly different at the 95% level of confidence.

In almost every case one cob was produced per plant, 2 cobs were produced on one plant. In the U1 series a few tiny cobs of less than 10 gms were visible, these were documented but not counted. The strokes between figures show the split of containers. From these figures one can deduce the means and standard deviations. The means shown are the total cob weight of all plants produced under that urine regime.

Discussion of results

Maize responds very well to urine application when grown in basins, under experimental conditions. Compared to maize grown in basins without urine application the yield increases by factors which ranged between **6 and 35 times** when fed urine. These are significant improvement in crop yield with the only source of available extra nutrients being released from the urine.

These and other results from an extensive series of maize trials reveal that the production of maize could be increased on poor sandy soil, by the application of urine alone, but that if the sandy soil had humus added, then the production went up further. Mean maize cobs yields of **4.3 gms** for poor sandy soil (Epworth) irrigated with water only went up to **82.3 gms** when soil was treated with urine only (125mls per plant per week) and to **131.28 gms** when the poor sandy soil was mixed in equal proportions with ***Fossa alterna*** humus and also treated with urine. This increase is partly due to the presence of the nutrients in the ***Fossa alterna*** soil, but also due to the increased number of nitrifying bacteria present in the humus which converts the urea and ammonia in urine into nitrate ions which can be taken up by the plants. The addition of ***Fossa alterna*** humus to poor Epworth soil in equal proportions, but without urine treatment, only increased mean cob weights from **4.3 gms** to **27.9 gms.** This indicates that the presence of humus is an import requirement if the nitrogen in urine is to be converted into a usable form which the plants can take up. It also shows that both urine and eco-humus enhance the value of the other and the optimum is to use them together.

Efficiency of use of urine

In all cases the yields of maize (and vegetables in earlier experiments) was the highest when the highest dose of urine was applied, but these were often wasteful of urine. The results reveal that a lower dose of urine was more effective in terms of grams of cob weight in relation to millilitres of urine applied. So a balance must be struck between yield and efficiency of use of the urine. This concept is best revealed in the large M14 maize experiment, which is described briefly below.

The M14 experiment

In this experiment 3 maize seedlings were planted in each of 24 ten litre basins filled with Woodhall Road topsoil (which has few nutrients - see soil analysis). The seedlings were planted on 30thOctober 2002. The following schedule of watering/urine treatment was given:

3 basins irrigated with water only
3 basins irrigated with 10:1 water/urine mix, once a week + additional watering (U4)
6 basins irrigated with 5:1 water/urine mix, once a week + additional watering (U3)
6 basins irrigated with 3:1 water/urine mix, once a week + additional watering (U2)
6 basins irrigated with 3:1 water/urine mix, three times a week + additional watering (U1)

The application of the water/urine mixes began on 4th November 2002. 0.5 litres of the water/urine mix was applied to each basin. The plants were kept turgid at all times with artificial watering by watering can. Thus plant stress resulting in wilting was avoided. For the first two weeks little difference was noted in the growth of plants. After one month, the water only fed maize began to lag behind all other plants, which all showed lush growth. As the plants grew and their nutrient requirement increased so did the appearance of the maize begin to change. After two months growth, the U1 treated maize were notably greener than all other plants. Maize plants in which the nutrient requirements were not fully met by the urine treatment showed the features of nutrient deficiency such as paler, smaller green leaves with basal leaf yellowing and smaller cobs. This occurred in all plants except those fed the strongest U1 treatment. As plants like maize mature, nutrients held within the plant itself may be redistributed into new growth. In this case, nutrients taken up by the plant and even within the plant are directed to new leaf and cob growth. Older leaves turn pale and wither. The cobs were harvested on 30th January 2003, three calendar months after planting the seedlings. This gave 12 weeks of urine treatment in this case. Each cob was weighed and means for each urine schedule were calculated. Figures are given below for urine application to maize with corresponding cob yield and also millilitres of urine required per gm. of cob yield.

Urine application to maize with corresponding mean cob yield

Liquid feed	No. weeks	Total urine applied per plant	Mean cob weight
Water	12	none	**6gms**
U4*	12	180 mls	**62 gms**
U3*	12	324 mls	**138.18 gms**
U2*	12	480 mls	**169.61 gms**
U1*	12	1500 mls	**211.25 gms**

These figures reveal, as in the M8 trial, that the maize cob output is related to the urine input and that the highest urine input results in the highest output of cobs in terms of overall weight. However the figures also reveal that the most effective use of urine is not found in this highest dose rate as the chart below shows.

Millilitres of urine required per gm. weight of cob yield

Liquid feed	Urine input per plant per week	Mls urine required per 1 gm cob yield
U4	15mls	2,90 mls per gm cob
U3	27mls	2,34 mls per gm cob
U2	40mls	2,83 mls per gm cob
U1	125mls	7.10 mls per gm cob

Thus in terms of the most effective use of urine, the U3 treatment was the most effective, as this used 20% of the maximum urine dose to produce 65% of the maximum cob output. The U2 treatment used 33% of the maximum urine dose to produce 80% of the maximum cob output. These figures indicate that high doses of urine are not the most effective way of using urine. But cob size is a factor of importance considered by the consumer, and cobs produced in the U3 trial might have been considered undersized. Thus one looks at the U2 treatment as the guide. If the same amount of urine used to feed the U1 application was used to feed three times the number of plants at the U2 application rate (about 40mls per plant per week diluted with 3 X water), then the overall yield of cobs would have been increased by a significant 2.4 times. In fact heavy doses of urine are wasteful and not efficiently converted. If urine is available in sufficient quantities, then an effective treatment for maize would be the U2 treatment for the 1st and 3rd third months and U1 treatment for the second month. This regime would use a total of 820mls urine per plant with the possibility of little wastage of urine and producing a good cob weight per plant. The largest cob produced in the trial weighed **356 gms**. Remarkably the plant grew 2.1 m high on just 100mm depth of soil.

Total yield of cobs from maize planted in three 10 litre basins in the M8 trial. On the left the maize was fed 1750mls urine per plant over the 3.5 month growing period, resulting in a crop of 954 gms. A reduced crop resulted from reduced input of urine (middle). Maize plants on the right were irrigated with water.

The M14 experiment

24 ten litre cement basins were planted with maize seedlings on 30th October 2002 and watered for a week. The application of varying concentrations of a water/urine mix then began.

Photo taken on 3rd December 2002 after about 5 weeks of water/urine application. The dramatic differences in growth rate of plants is easy to see – water treatment only on extreme left and maximum urine treatment on extreme right with intermediate applications between.

Photo also taken on 3rd December 2002. Vigorous growth of maize can be seen with the highest urine application on the right. The maize was harvested on 30th January 2003, nearly 2 months later.

The M14 maize harvest

A single photo shows the effect of different amounts of urine applied to maize plants over a 3 month period. On the left (U1) the plants have been fed a 3:1 water/urine mix three times per week (125 mls per plant per week). This has led to a mean cob weight of 211 gms. The 3:1 mix was applied to the U2 group once a week (40 mls per plant per week) and has led to a mean cob weight of 169 gms. A 5:1 mix was applied to the U3 group once a week (27 mls per plant per week) and has led to a mean cob weight of 138.2 gms. A 10:1 mix was applied to the U4 group once a week (15 mls per plant per week) and has led to a mean cob weight of 62 gms. Those plants fed water only produced a mean cob weight of only 6 gms. 99.4% of the total cob mass shown in this photo is derived from the nutrients provided by the urine.

Closer look at maize cobs produced at the lower end of the application range and with no urine. All growth over and above the mean of 6gms per cob is due to urine application.

Maize trials in the fields.

The result of maize trials undertaken in basins shows a dramatic influence of urine treatment. But the conditions are unusual. Maize is rarely grown in containers and more often in very large fields and backyard gardens where there is space, Also urine treatment works particularly well in containers because the nutrients derived from urine are confined in the soil held by the container. In the cases described in this book, that is just 10 litres of soil. When urine (or other methods of fertilising) are used in gardens or in the fields, the fertiliser is placed in the ground in unconfined conditions. That means that the full effects of the fertiliser may be partly lost. Heavy rain, for instance may drive nitrogen fertiliser down deeper in the soil and much of it may be lost to the plants. Also there may be a tendency to spread fertiliser too thinly if it is costly. Whilst vegetables may best be grown in containers, maize rarely is, so it is important also to test the effects of urine in working maize fields. This has been undertaken in the Marlborough vlei, Harare.

Two sections of the maize field are of particular interest, named areas A and B. At first urine was applied diluted with water to section A, as in the garden trials, but this quickly proved to be impractical. The water was too heavy to take to the fields. The urine was heavy enough. Neat urine was applied in a small hollow made near the plant - watered in by natural rainfall.

Area A.

Maize in area A was planted in mid November 2002. The area was divided into two sections. Urine application began on one section on December 11th 2002, with weekly applications being made until February 28th 2003. Urine was applied to the site of seed planting (planting station) where normally more than one seed is planted. No urine was applied to the second (control) section, this being irrigated with natural rainfall only. The first 3 urine applications were made with 125mls urine diluted with water, the remaining applications with neat urine, when the dilution method proved unpractical. A total of 1275mls urine were applied to each planting station during 12 weekly applications. The maize cobs were harvested on 31st March 2002 after 4.5 months of growth. Mean cob weight for the section without urine was **154.11gms** (n= 85). Mean cob weight for the urine treated section was **197.7gms** (n= 70). The urine treatment led to an overall increase in cob weight of 28%.

Photo of maize field (area A) taken on 19th December. The bamboo sticks are markers. On the left of the marker the maize was treated with 100mls urine per maize station per week in a single application. On the right of the marker no urine treatment was give.

Area B.

Maize in area B was planted in mid December 2002, which was late in the planting season. The area was divided into three sections. Section 1 (about 80 planting stations) was irrigated with normal rainfall only. Section 2, also of about 80 planting stations was treated with 100mls urine per week for 9 weeks (Dec.19th 2002 – Feb. 28th 2003). Section 3 (about 80 planting stations) was treated with normal fertilizer. 10gms of a NPK 1:2:1 fertiliser were applied on 28th December and 10 gms of a NPK 5:1:2 fertilizer were applied on 29th January 2003. This double treatment is standard for maize in Zimbabwe. A total of 900 mls urine were applied to each maize station during 9 weekly applications. The maize cobs were harvested on 15th April 2003 after 4 months of growth. Mean cob weight for the rainfall irrigated section was **103.07gms** (n= 104). Mean cob weight for the urine treated section was **143.87gms** (n= 102). Mean cob weight for the chemical fertilized section was **166.22gms** (n= 135). The urine treatment led to an overall increase in cob weight of 39% over the rain irrigated section. The chemical fertilizer urine treatment led to an overall increase in cob weight of 61% over the rain irrigated section.

Photo of maize field (area B) taken on 19th December. The bamboo sticks are markers. On the left of the marker the maize was treated with commercial fertiliser. On the right maize was treated with a single100mls application of urine per maize station per week.

Maize growing on area A in January. Urine treated on left, rainfall treated on right.

Area A (left) and B (right) at the time of cob harvesting.

Discussion on urine treatment of field maize

The field maize trials reveal that urine treatment at the rate of 100mls neat urine per planting station per week over a 3 month period does increase overall maize cob weight by between 28.2% (area A) and 39% (area B). This is less than the effect of conventional chemical fertiliser which increased overall cob weight by 61% compared to maize irrigated with rain only. However the urine treatment cost nothing, although some effort was used in applying urine to every plant once a week. It is possible that a similar effect might have been noted had larger amounts of urine been applied less frequently, but this has not been examined.

It is interesting to note that the final harvest of maize was not only influenced by fertilizer treatment but also by planting time. Rain fed maize planted at the recommended time (mid November in area A) yielded a higher cob weight (**154.11 gms**) than rain fed maize cobs planted late in mid December in area B (**103.07gms**). In fact rain fed maize planted in November produced a better cob weight (**154.11gms**) than urine fed maize planted in December (**143.87gms**) and nearly the same as chemically fertilised maize planted in December (**166.22gms**). These figures reveal what is already known – that the success of maize production lies largely in early and successful planting.

The pattern of the rainfall also plays a significant part in maize production. Early rains may prompt planting, but if the rainfall dies away, replanting may be required. During the season under test, the early rains faded away and led to plant stress which was later partly relived by heavy rains - but too late in the maize season. These rains continued but came too late, leading to some rotting in later planted maize.

The effect of urine treatment was greater with later planted maize (39% increase following 900mls application per station) compared to earlier planted maize (28% increase following 1275mls application per station). Inspection of the overall maize field revealed that in some areas plants grew better than in other areas. In area A, the natural soil condition led to a healthier crop than the poorer soil condition of area B. The effect of urine (or fertilizer) treatment may be more obvious in areas of poor natural soil. However the overall effect on growth results from a combination of effects caused by the natural soil condition and any influence by imported nutrients. Overall the best urine treated maize crop came from area A (**197.7 gms**) compared to **143.87gms** for area B. It is known that the effect of urine treatment varies considerably, depending on the nature of the soil, its phosphorus status and its capacity to convert urea into nitrate and also the soils natural fertility. Vlei soil was clay like and not the best medium for converting the nutrients held by urine into a form suitable for plant growth.

The effect of urine and other fertilizers on plant growth is also influenced by the dose and therefore the number of plants that take up a given dose. It is traditional in Zimbabwe that 2 or 3 maize seeds are placed in each "planting station" and both chemical fertilizer and urine were applied to each station as if to a single seedling. But in fact the dose, in each case was distributed between at least 2 and sometimes 3 plants, thus diluting the influence. Also in natural fields, the fertilizer, whether chemical or urine, is also utilised by weeds which often grow rampantly in maize fields. This was the case in this study.

Also in maize grown on the fields, heavy rains may flush away the nutrients available in the limited quantities of urine available, and this applies particularly to the nitrogen. Both phosphorus and potassium seem to bind better with the soil and are less easily flushed away. The relatively small quantities of urine applied close to each plant are dispersed by the rain over a larger volume of soil, as they are not contained in any way. Even for commercial fertilizer, heavy rains are known to reduce the effectiveness of the treatment, since the minerals, particularly nitrogen can be flushed down into deeper layers as the rainwater tops up the aquifer. They are then of no use to the plants.

With all these variable factors at play it is not surprising that the overall weight of harvested cobs in the natural vlei site was less than that harvested in the artificial environment of the cement basin when urine was applied. Mean cob weights for urine applied maize on the vlei are 197.7 gms and 143.87gms respectively (mean **165.78gms**). This is less than the mean weight of urine fed maize in artificial basins - **211gms** (U1 treatment) and **169gms** (U2 treatment), respectively. This is easy to explain because the conditions of growth were more closely regulated in basins, where plants were well watered, well fertilised with nutrients being retained in the basin. Also measured doses of urine were applied per plant and not per planting station, leading to individual plants being fed properly in basins. Also rampant weed growth was controlled in basins. Yet another effect with artificial irrigation is that the maize can be (and was) was planted early, which also helps to increase the final yield, as the hottest parts of the year (October and November) occur before the main rainy season starts.

Overall conclusions of urine trials

These various trials show quite clearly how valuable urine can be as a liquid feed for the range of plants studied so far. The study also reveals that application in small containers may be more effective than on beds, although this will not be the normal method of growing vegetables.

The trials show that for most leafy vegetables a significant increase in yield can be expected from the application of urine, which is best applied diluted with water at a ratio of 5 parts water to one of urine once per week. Higher yields are obtained with higher doses of urine, so a 3:1 application three times per week will give a higher overall yield than the same mix applied once per week. However, all experiments reveal that this high dose is wasteful of urine and urine application either once or twice a week is a far more effective use of the urine derived from a family. This is because it can lead to the production of greater overall yields, since the lower dose of a fixed volume of urine can be used on a larger number of plants, which overall will provide a bigger harvest. If more urine is available, a lower dose can be used at first followed by a higher dose during the main vegetative growth period, finalising with a period of lower application prior to harvesting. Prolonged use of a higher dose affects plant health and is not desirable.

Plant trials were also conducted with onion growing in 10 litre containers, and followed the routine employed in the other trials. Seedlings were grown from seed in seed trays and transferred to 10 litre basins at the rate of 10 or more plants per basin. Using a combination of humus like soil and the 3:1 application up to 1.4 kgs of onion could be reaped from a single 10 litre basin within 6 months. An average crop was 1kg per basin. This is a fair yield of onions per basin. Onions respond readily to urine treatment. As in all these trials leading to a practical application, the 3:1 water/urine, applied once a week, is perhaps the best guideline to be followed, as it is less demanding on the gardeners time and is effective. But a 5:1 application will work nearly as well. The same applies to flower beds. Many flowers respond well to urine, the hardy and colourful marigold being just one.

The enormous value of urine must be accepted without question, despite the fact that the proportions of the major nutrients held in urine are not ideal as a general liquid fertiliser (11:1:2 for NPK). A ratio of 2:3:2 for NPK might have been better for vegetables, where more phosphorus assisting the formation of root growth, and potassium in the formation of fruits, such as tomato would have been preferable. However urine is universally available at no cost and therefore its minor limitations must be accepted, because its advantages far outweigh its deficiencies. Urine can be manipulated in various ways, such as fermenting with humus (the Mexico method) or with comfrey. The phosphate proportion can also be increased by sedimenting out the salts of phosphate (struvite) by decanting the upper layers of urine after settlement and remixing with water. Also small amounts of single super phosphate fertiliser can be added to the diluted water/urine mix. . However, perhaps the easiest and most logical method is to use urine in combination with eco-humus derived from the eco- toilets. In this way the humus with its higher proportion of phosphorus and potassium, complements the subsequent use of urine with its very generous supply of nitrogen In the end the great value of urine lies in the undisputed fact that it costs nothing and there is no place on earth where people live that it is not available.

Potential yield of vegetables and maize using annual family urine production

In terms of urine output, an annual production of at least 2000 litres is theoretically possible from a family of two adults and three children, even with some wastage. However an average family may contain and use less than 400 litres per year in practice (Edward Guzha pers.comm.). There are many ways of collecting urine in the homestead, filling bottles, plastic containers and potties perhaps being the most likely in the absence of a urine diverting toilet. It is interesting to speculate how much vegetable growth and maize cob yield would result from the application of 2000 litres of urine. The following figures are calculated using data from the experiments described in this book.

Crop	**mls urine required per gm of crop.**	**Potential annual crop**	
Lettuce	5.5 mls per gm of crop	362 kg/yr	or
Spinach	5.0 mls per gm of crop	400 kg/yr	or
Covo	7.3 mls per gm of crop	274 kg/yr	or
Tomato	4.1 mls per gm of crop	486 kg/yr	or
Maize	2.8 mls per gm of crop (U2 application)	704 kg/yr	

It is clear that the potential gain in yield resulting from total annual family urine application to green vegetables and maize is far greater than for eco-humus application alone. It is interesting to compare the figures above with the improvements in the potential annual production of tomato (73 kg), spinach (27kg), covo (17 kg), or lettuce (45 kg) derived from the humus alone. Thus, the total potential value of applying urine for increased crop yields of maize ands green vegetables is far greater than eco-humus by itself. The difference perhaps is that the entire volume of the eco-humus taken from the toilet can be easily stored and put to use by mixing into vegetable beds, whilst only part of the urine may be used because it is far more difficult to store in bulk. Also urine is less effective on poor sandy soils which are common in Africa and best used in combination with humus of some sort to get the desired effect.

Whilst such figures are impressive, the fact remains that currently most urine goes to waste, even in projects using urine diverting toilets. It is possible that promoting the enrichment of soil with eco–humus first, which is already widely practiced by owners of the ***Fossa alterna***, and then building on to this the practice of applying urine to increased of vegetable production further, will make a lot of sense to the users. Such a process is currently being encouraged.

In the homestead there are many ways of collecting urine and a urine diverting pedestal or squatting platform is not essential. In several countries in East and South East Africa (Malawi, Mozambique, Zambia), the decision about which eco-san technology to use, where a choice is give, is based on factors such as affordability and ease of construction and management. Very often the urine diverting method is rejected on account of its relatively high cost and complexity. In practice people respond very positively to the production of humus derived from their toilets and this is willingly applied to the land. The demonstration of a rich, crumbly and pleasant smelling humus formed by mixing excreta, soil, ash and leaves is a powerful selling point for ecological sanitation and has led to the main developments and uptake of low cost ecological sanitation in Malawi, Mozambique and Zambia. This reaction is positive for the uptake of recycling and its effect should never be underestimated.

The limited volumes of humus, and to a lesser extent urine produced by a family, means that these products are better used in the backyard garden environment rather than on larger fields. In the backyard there is more control on the precious resources and the result is more easily seen and appreciated. This applies to both eco-humus from the family latrine (***Fossa alterna*** and also urine from various sources. The combined effect of the application of these resources may represent, for each family, a huge increase in vegetable production, especially in areas where the soil is poor or access to manure or commercial fertilizer is difficult or expensive. Barren gardens may be turned into gardens of plenty over the years. Such a possibility, coupled with the convenience of an effective and low cost toilet system makes good sense to townspeople and villagers alike. But as always – ***Time will tell!***

16. Gardening techniques that assist eco-san supported food production

We have now discussed the methods of building and using eco-toilets and how their produce may be used with beneficial effect in the garden. But some extra technique will also help too. The production of vigorous healthy vegetables requires effort and also a knowledge of the soil and the plants themselves. Some vegetables are easier to grow than others. Most basic top soils do not have sufficient nutrients in them to provide healthy vegetable growth. Such soils require extra ingredients added to them in the form of humus, compost, manure or organic liquid food or ideally a combination of these. A good soil texture as well as an adequate level of soil nutrients is also very important. And the other vital component is water - without it no plants can grow and plants supplied with insufficient water become stressed and cannot provide an abundant harvest.

Countless thousands of books have been written on vegetable gardening, and there is little need to repeat what has been written so many times before. However the writer has used a few special techniques which he has found particularly valuable in eco-san assisted vegetable production. These include the production of compost, leaf mould, liquid plant foods, seedling production, mulching techniques, worm farming, watering techniques, etc. A few of these are described here.

1. Compost making and application

The compost heap is a familiar site in most well run vegetable gardens. Compost can be made in piles, pits and every sort of container imaginable (drums, tyres, wooden and brick enclosures, buckets etc). A compost heap is a bacteria and fungus farm which breaks down all sorts of organic matter - with the presence of both air and moisture being essential.

Compost heaps

These are the most common. The largest component is vegetable matter, with smaller amounts of soil and manure being added in layers. Typically a 150mm deep layer of vegetable matter (chopped up vegetables, leaves, crop residues, weeds, grass, tree prunings, straw, organic kitchen wastes etc.) is laid down first. This vegetable matter is covered with a 50mm deep layer of manure, which can be taken from the urine diverting toilet or from the droppings of various animals (chickens, goat, horse, dog, cattle etc). Then a thin third layer, about 25mm deep of soil or soil and wood ash is added over the manure layer. Then another 150mm deep layer of vegetable matter is added on top and the process of building up the “sandwich” is repeated until the pile is about a metre high. The pile should be kept moist at all times but not wet.

The use of urine as an activator is recommended - it should be diluted with water about 2:1 or 3:1 and applied to the heap. Air vents can be added and ideally the pile should be turned twice during the three month period when the compost is forming. However this may be easier said than done. The resulting compost is dug into beds and mixed with other soils to enrich them.

Full compost heap at the Eco-Ed Trust, Mutorashanga. The base layer of vegetable matter has been laid down to a depth of about 150mm and has been coveted with a 50mm deep layer of manure (including human). This has been covered with a thin 25mm layer of soil (with a little lime). The next layer is vegetable matter again and the process is repeated. Thanks to Jim Latham and Eco-Ed Trust.

Compost pits

The same process can be carried out in pits below ground level. In fact, during its first year of operation, the second pit of the ***Fossa alterna*** can be used to make compost. However it is equally well used to make leaf mould. It can also be filled with a mix of leaves, soil and animal manures and used to grow comfrey or other vegetables. There are many uses of small shallow pits, not least that used for making humus from human excreta, soil, ash and leaves.

The second pit of a *Fossa alterna* in its first year can be used as a compost pit.

Compost baskets

A simple compost maker can be made from a tube of chicken wire. A piece of 12mm chicken wire 0.9m wide and 2m long is formed into a tube. The ends of the wire can be brought together and the twisted together to make a tube. Such a basket is self supporting if leaves alone are added to make leaf mould, but it will not be self supporting when a mix of vegetable matter, leaves and manure and soil is held within. So four stakes or cut bamboo must be held firm in the soil around the basket to keep it upright. Once the basket is secure add leaves and a variety of other vegetable matter to the base - about 150mm deep. Then add a layer of manure about 50mm deep (this can include buckets of human faeces and soil taken from the ***Skyloo***) topped up by a layer of soil 25mm deep. Fertile topsoil is best. As an activator, a mix of urine and water (about 4 litres urine to 8 litres water) can be added when the basket is half full. Then repeat the additions of vegetable matter, manure and soil. Add some more of the diluted urine when the basket is full. Adding some compost from another pile helps. Keep moist by watering with the water/urine mix or plain water from time to time. After about three months the end result should be pleasant smelling crumbly dark brown compost which can be applied to the vegetable garden at the rate of a 10 litre bucket full per square metre.

Chicken wire baskets held up with bamboo poles contain compost - a mix of vegetable matter, manure and soil in layers. Behind there are two similar baskets made of chicken wire which are particularly useful for making leaf mould. The leaves are placed inside the basket with very thin layers of soil added. Often no soil is added at all. They are much lighter when filled with leaves only and do not need support. A very useful size is where these baskets are cut in half and about 45cm high. The baskets are about 65cms in diameter. The baskets can be scattered about in the garden where the leaves are falling.

Cement compost jars

A combination of vegetable matter, thin layers of soil and manure can also be built up in composting jars made of cement. In fact split cement jars (30 litres capacity) are ideal for composting human faeces together with soil (see section on ***Skyloo***). Larger 80 litre jars can also be made in cement. A mould made from a plastic dustbin is ideal. The plastic dustbin is cut in half and used as a mould. The two halves of the resulting cement jar, once cured are wired together and the build up of ingredients inside can begin. Vegetable matter (from garden and kitchen), manure and soil are added in layers and watered down. It is this watering which can contain urine - a mix of 3 parts of water to one of urine will help to activate the pile and also add nutrients to the final compost.

The writer has used this method to utilise dog manure in his garden. The dog manure is swept up and added to the 80 litre split cement jar composter. Vegetable matter discarded from the kitchen and elsewhere is also added and covered with a layer of soil The compost produced is rich in nutrients as the table below shows. Four such jars have been built and the soil, dog manure and kitchen wastes are placed in each in rotation. It takes a year to fill all four jars, thus the period of composting before subsequent extraction is one year. The compost when mixed with topsoil is an excellent growing medium for vegetables. The ideal mix for growing a variety of vegetables consists of 50% of this jar compost and 50% leaf mould. 80 litre jars of this type could also accept the buckets of faeces and soil from the ***Skyloo*** to replace the dog manure. Currently a series of smaller 30 litre split cement jars are used for this purpose and have proved over several years to be perfectly satisfactory for this task.

. **80 litre cement composting jars**

Nutrient levels in jar compost

The following table shows how the combination of dog manure and organic kitchen wastes in combination with garden topsoil can be used to make a valuable compost. Nitrogen and phosphorus in ppm and potassium (K), calcium (ca) and magnesium (mg) in ME/100gm sample

Soil source	pH	N	P	K	Ca	Mg
Woodhall Road base soil	6.2	27	32	0.63	9.68	2.30
80 litre jar soil	7.2	314	171	1.00	67.38	17.52

When the jar soil is combined with Woodhall Road topsoil, all nutrient levels are increased together with soil texture. It is a good way of getting some benefit out of dog manure!

2. Leaf compost making and application

Leaf compost (sometimes called leaf mould) is the humus like material formed when leaves break down. The process takes place in nature constantly under trees or in the woodland or forest. Forest humus is the complex material originating from the decomposition of both animal and plant residues by micro-organisms. It forms the fertile "forest floor" in which so much life abounds. Humus provides food for bacteria and fungi and also a medium in which they can work. Different groups of microbes are vital for transforming organic residues to nutrients which can be used by plants. Microbes associated with the root system encourage mycorrhizal association - channelling of nutrients into plant roots through the fungal threads. Humus also improves the texture of the soil making it more crumbly and also improves its water and nutrient retaining capacity.

Leaf compost is the end result of a natural decay of leaves and is performed mainly by action of fungi, but there is also some bacteriological breakdown. The normal compost heap in which vegetable matter, manures, and soil are mixed in layers is also broken down as a result of fungal activity, but bacteria are very active in this process and the presence of air is essential.

If plenty of leaves are added to the ***Fossa alterna*** pit during the filling process, then there may be little need to add any more humus (including leaf compost) to the final mix of eco-humus and soil to make an ideal growing medium for plants. However if a poor soil is added to the pit, there will almost certainly be a need for additional humus to be added. Leaf compost is one source of humus which is easily made, costs nothing and may be readily available. Its effect on improving the soil, texture and level of nutrients is very significant.

Leaf compost helps to improve the soil by improving its physical characteristics, making it more crumbly and also improving its water retaining properties as well as releasing plant foods into the soil. It is thus a most valuable material and every effort should be made to utilise it in vegetable production associated with ecological sanitation.

How to make leaf compost

Leave compost can be formed artificially when leaves are stacked up in heaps and watered. Leaf compost can be formed by watering leaves contained in chicken wire baskets, half drums, brick enclosures, pits, plastic bags etc.

If dry leaves are stacked up in piles, or even in chicken wire baskets and left dry they do not change much. Like paper, they retain their characteristic for years. If the leaves are soaked in water they begin the rot and break down and the temperature rises. It is the fungi (*Ascomycetes, Paco Arroy, pers.comm)* present on the leaves which multiply and do much of the breakdown of the leaves, but also bacteria are active too. The formation of leaf compost is a relatively slow process because the cellulose in the leaves must be broken down and this takes time. However there is much variation. The temperature increase varies from one leaf type to the next, and this also relates to the rate of breakdown. Indeed in terms of leaf compost production there is a great variation between leaves, some are easier to process than others. Thinner leaves like bougainvillea and Mexican apple are easy to process and actually heat up quickly when water is added. Temperatures of 60 degrees C can be reached in just a few days, indicating that bacteria are very active in this stage, but are not maintained and temperatures between 20 - 35 degrees C are more common during the formation of leaf compost. Leaves like Kenya coffee, guava and avocado seem to heat up less and take longer to form the leaf mould - they have thicker leaves.

Making leaf compost in wire baskets

This may be the best way of making leaf compost. A piece of 12mm chicken wire 0.9m wide and 2m long is formed into a tube. The ends of the wire can be brought together and the twisted together to make a tube. When filled with leaves the wire basket is self supporting. This tube can be cut in half to make two leaf mould baskets each 0.45m high. The shorter baskets are actually more convenient. Experience has shown that if dry leaves are broken up first then leaf mould production is accelerated. One way is to stack them in the "basket" and pound them with a pole. For the luckier ones, an excellent method is to stack the dry leaves in a pile in the garden and run the lawn mower over them. The technique involves raising the mower over the leaves and gently lowering the rotating blades over the leaves. They will immediately be cut up. This process is continued until all the leaves are cut up. The volume of cut up leaves may be one third or less of dry un-pounded leaves. It is these leaves which are introduced into the basket and compacted. They are then soaked with water and covered with a sack. Water loss can be reduced further by wrapping plastic sheet around the basket.

Within a day the temperature starts to rise significantly, but the temperature attained will depend on the type of leaf. A mixture of Bougainvillea and Mexican apple leaf was ideal and rose from ambient temperature of around 20 degrees C up to over 60 degrees within 4 days of packing in a basket and soaking. Leaves of Kenya coffee, guava, and avocado only reached temperatures in the 20's having been processed in the same way. Both Bougainvillea and Mexican apple leaves are thinner than the leaves of Kenya coffee, guava and avocado, and thus more easily broken down. The chart beneath provides a temperature chart.

Date	**Bougainvillea and Mexican apple**	**Kenya coffee, guava, avocado**
5th August 2002 (5.00pm)	leaves placed in basket	leaves placed in basket
5th August (ambient temp.)	20	20
7th August (8.40 am)	54.6	22.4
8th August (7.00 am)	60.2	22.2
10th August (9.10 am)	56.0	20.9
11th August (noon)	41.9	20.5
12th Augsut (8.15 am)	41.3	22.2
15th August (noon)	38.6	27.1
16th August (5.30 pm)	36.9	26.1
18th August (9.00 am)	27.2	25.2
20th August (9.00 am)	23.2	23.3
21st August (7.30 am)	22.7	22.3
25th August (9.00 am)	20.8	20.0

The rate of leaf compost production is accelerated considerably if the leaves are cut up first and then enclosed in the basket and surrounded by plastic sheet. Leaves can even be contained within large plastic bags within the basket. Whilst leaf compost may take several months to form heaps or even open baskets, if the leaves are soaked and contained within baskets surrounded by plastic sheet or contained in plastic bags, thus retaining constant moisture, the rate of production is increased. An excellent leaf compost made from Bougainvillea and Mexican apple leaves was ready for use after six weeks in the basket surrounded by plastic sheet and after 4 weeks when the leaves were enclosed in a bag within the basket. In both cases the dried leaves had been chopped up before being placed in the basket.

Soil analyses were undertaken on both the leaf compost made in the basket and one processed in the bag. In both cases an excellent leaf compost was made which were very rich in nutrients. Figures for pH, nitrogen and phosphorus in ppm and potassium (K), calcium (Ca) and magnesium (Mg) in ME/100gm sample are shown below.

Soil source	pH	N	P	K	Ca	Mg
Leaf compost (in basket)	8.2	256	344	13.92	29.86	9.42
Leaf compost (in bag)	7.8	267	294	8.50	25.40	6.35

These figures show what a very valuable product leaf compost is, rich in all the important plant nutrients.

Making leaf compost in steel drums

A 200 litre steel drum can be cut into half and also used as a leaf composter. This method was tried at Woodhall Road with success. Layers of leaves were placed in the half drum and covered with a thin layer of soil and then more leaves were added. A good leaf compost was prepared in about 6 months. This leaf compost was analysed at the soil testing laboratory. Figures for pH, nitrogen and phosphorus in ppm and potassium (K), calcium (Ca) and magnesium (Mg) in ME/100gm sample are shown below.

Soil source	pH	N	P	K	Ca	Mg
Leaf compost (in drum)	7.6	239	255	0.60	40.20	14.80


On left chicken wire baskets used to make leaf compost. This is the most effective method. Water is applied to the leaves to keep them moist. They retain water better if the basket is surrounded by a plastic sheet or sack. It also helps to cover the leaves with sacking or plastic. On the right two half steel drums with leaf compost. Later they were turned into worm farms

Making leaf compost in brick composter

Bricks can also be used to contain the leaves. These are built up without mortar to form a brick box. The unit used at Woodhall Road measures 0.95m X 0.70m X 0.3m deep. The leaves are stacked in the brick box and watered and covered with newspaper. Within a few days they contract in size and more leaves are added, being covered with the newspaper again. After several months the decomposed leaves can be removed and bagged ready for mixing with other soils used in eco-san and other gardening projects. This leaf compost was also analysed at the soil testing laboratory.

Figures for pH, nitrogen and phosphorus in ppm and potassium (K), calcium (Ca) and magnesium (Mg) in ME/100gm sample are shown below.

Soil source	pH	N	P	K	Ca	Mg
Leaf compost (in brick composter)	7.4	540	266	9.00	29.1	12.90

The overall conclusion is that leaf compost is a valuable and indeed even vital component to eco-san. Obviously where there are no trees there can be no leaf compost, but where trees are growing it is readily available form of humus and also nutrients which are of the greatest value to the organic farmer. What is so important is that leaves are added to the shallow pits systems used in eco-san - like the ***Arborloo*** and the ***Fossa alterna***. When soil alone is added, nutrient levels of the final humus can rise significantly. The addition of leaves as well, and as many as possible, improves the texture of the final product considerably. In the initial trials of the ***Fossa alterna*** at Woodhall Road in mid 1999, leaves were added to the pit contents together with soil and human excreta. The humus like qualities of this mix were much appreciated and led to the use of the word "humus" as a description of the product. Without leaves (or other vegetable matter) being added to the shallow eco-pits, the soil produced tends to be similar to the soil added, sandy, clayey grey, dark and light etc. The addition of humus forming matter like leaves provides the extra qualities that good soil requires. Leaf compost added to sandy soils also assists in the conversion of ammonia to nitrate which the plants can use.

Unmortared bricks stacked up in a box shape make a good leaf compost maker

Use of leaf compost in eco-san

The final leaf compost is mixed with other soils and also can be mixed with soil from the *Fossa alterna*. An excellent combination is one third *Fossa alterna* humus, one third leaf compost (or other compost) and one third topsoil taken from the vegetable garden. This has been tried in several experiments. The leaf compost provides improved physical properties to the soil as well as providing extra nutrients which are released over time. Another excellent mix is 50% compost jar humus and 50% leaf compost. The jar humus can include human faeces as well as animal faeces. In this case it is allowed to compost for one year before use. But the greatest value of leaves in eco-san is when they are allowed to compost in the shallow pits of the *Arborloo* and the *Fossa alterna*. As we have seen they provide many improved properties to the final humus, not least improving nutrient level and air content and thus improving composting efficiency but also absorbing urine which greatly assists in the composting process.

3. Liquid plant food

Plants grow best when there is a good balance of nutrients available. According to the organic farmer Lawrence Hills, if you have too much nitrogen available at once, you "lock up" the potassium,, as well as wasting nitrogen. Use too much phosphorus, and this too locks up potassium, whilst excess calcium is locks up boron. In tomatoes pale green leaves denote a shortage of nitrogen. Small blue green leaves turning purple shows a phosphorus shortage. This is particularly noticeable in rape - the leaves tips or sometimes the whole leaf turns purple as a result of a phosphorus deficiency. This often affects the older leaves and plants have the ability to transfer nutrients from one part of the plant to the other - providing the younger leaves with a higher proportion of nutrients. This obviously only happens if the soil is deficient in nutrients.

Swedish work which is well documented shows how valuable the urine is for providing quite a full range of nutrients (Wolgast 1993, Jönsson 1997 etc). However some plants, notably tomato and onion and even potato are known to require quite high levels of potassium and it is useful to investigate methods of bringing these special nutrient requirements to the vegetable garden. The Mexicans (Paco Arroyo pers.comm.) have shown that whilst urine is an excellent source of nitrogen, readily absorbed by plants and essential for leaf growth, when used on deficient soils there is not enough phosphorus and potassium which can reduce fruiting, particularly in those plants which have a high requirement for those elements. The Mexicans solved this by employing the red worm *(Eisenia foetida*), which produce castings containing a lot of phosphorus and potassium and also minor nutrients which the plants need and are not supplied by urine. Apart from garden humus and compost, liquid feeds made from manure and other materials rich in nutrients can be very valuable. The use of supplementary liquid plant food to satisfy the requirements of a wide range of vegetables is therefore of interest. One method is to add wood ash to the soil or even to the liquid feed. The writer has used this method and also turned to the comfrey plant as a valuable supplier of a wide range of nutrients. This can be supplied as a mulch or a liquid feed. The eco-humus is perhaps the most valuable supplier of these elements.

The value of comfrey

The comfrey plant (*Symphytum officianale*) has extraordinary properties of being able gather a wide range of minerals from the ground and hold it in the leaf. The leaves can be used in compost heaps directly or can be used as a mulch, but a valuable technique involves making a liquid feed from the comfrey leaves and applying this to plants. There are several methods available. One involves mixing water with cut up comfrey leaves and allowing the mix to ferment. The other involves adding cut up comfrey leaves to urine first, allowing the mix to ferment and then diluting with water. The method with urine is interesting because it produces a product which has the value of urine in it with an extra dose of potassium and other minor minerals.

This method of providing extra nutrients is interesting and particularly valuable for tomato and onion, which require a lot of potassium for the best results and it seems more than the urine alone may provide. Potatoes, beans, cucumber, squash, marrow and peas also require a lot of potassium and this may not be available in sufficient quantities in the urine alone. The urine and comfrey combination ensures that the best use is made of the urine which is a great nitrogen producer and comfrey which is a great producer of potassium. Both products do yield a wider rang of nutrients but in differing levels according to Hill.

3.1. Making comfrey liquor with comfrey and water

The simplest method is to chop up comfrey leaves and add them to water in a container with a lid and small hole drilled in the lid to let off gas. The comfrey is added at the rate of 1.5 kg chopped comfrey to 20 litres water. The mix is allowed to ferment for about four weeks before use. It can then be applied directly on the soil in which plants are growing. Application of about 0.5 litres per three plants or in a 10 litre container containing the plants three times a week can make a big difference to the plants.

3.2. Making comfrey liquor with urine and water

In this case a 24 litre bucket with lid is used. 1 kg of comfrey are cut up and added to 4 litres of urine. The mix is allowed to ferment for 10 days. A fermentation takes place and the leaves are rendered down and break apart. After 10 days an additional 20 litres of water are added to the mix which makes up the final liquor. This liquor, which should be stirred before application can be added to tomato at the rate of 0.5 litre per 10 litre container containing two or three plants (or two or three plants in a bed) once (or even 3 times) a week. Significant increases in the production of tomatoes can be achieved using this liquor as the chart below shows.

Production of tomato using urine/comfrey liquor

Plant	liquid food	frequency of application	weight harvested
Tomato	water	0.5 li X 3 per week	1680gms
Tomato	water/urine (3:1)	0.5 li X 3 per week	6084gms
Tomato	comfrey liquor	0.5 li X 3 per week	6230gms

These results show that the 3:1 water/urine mix was almost equally as good, urine/comfrey/water mix and more easily made From what Hill had said in his book and proven by much evidence, the tomato/comfrey mix should have produced a large crop. But it did not. Clearly other conditions were not ideal, like overcrowding in buckets and a soil which may have had too little humus. However the wide reputation of comfrey as an excellent plant food makes it a good choice where gardeners are not prepared to use their own urine. The recipe where cut comfrey is added to water alone is used in this case.

The comfrey plant is a most valuable addition to the garden. It can be used as the nutrient supply for a liquid plant food, with and without urine and also as a mulch. It is also an excellent addition to the compost heap. It also has medicinal properties. On the left cutting up comfrey and adding to water. This will ferment and provide a good plant food.

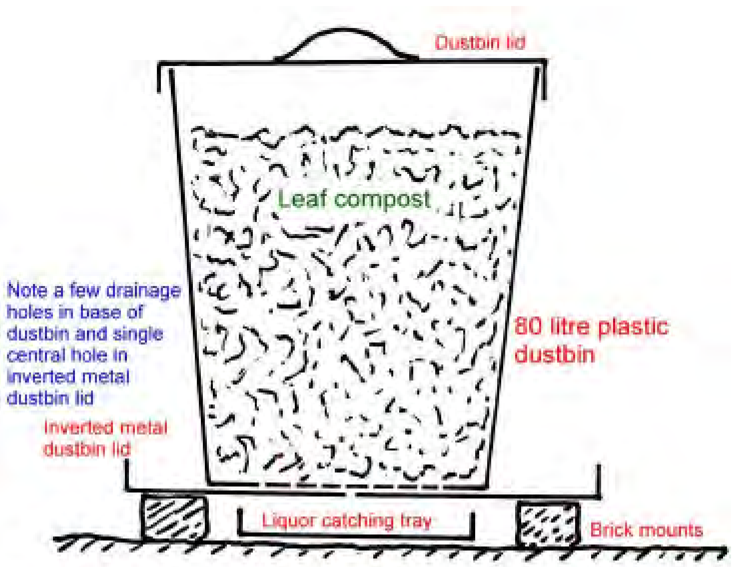
3.3. Making liquid plant food from manure

It is possible to make a liquid plant food from cow, horse, goat or chicken manure. It involves taking a bag of the manure and suspending it in a container full of water. A ten litre hessian bag of manure suspended in a 200 litre drum will work. The manure is bagged and suspended from a string into the water, and left for a week. It is best to cover the drum with a lid to stop any smell or fly problems. After a week the bag is removed, allowed to drain off and the brown liquid in the drum is stirred and then diluted with three parts of water to make the liquid feed. This can be applied to the vegetables with a watering can. The bag of manure can be placed back in a new drum of water and after a week used again diluted with about two parts water. If the bag is used a third time, the resulting liquor can be used neat on the plants. The manure can then be added to the compost heap. This method advocated by Tom Manson (see bibliography), which I have tried, works well. Eventually the bag rots – but a new one can be found.

There are several plant foods available on the market, the one known as Groesia is well known in Zimbabwe and has been available from the Marlborough Nursaries for decades. The secret formula no doubt has liquid manure in it, plus an assortment of additives. Even chemicals are sometimes added to the liquid manures and Manson recommends adding 2kg per 200 litres of ammonium nitrate for green vegetables or one high in potassium for tomatoes and potatoes.

3.4. Making liquid plant food from leaf compost

This a simple and effective technique for making a good liquid plant food which can be applied directly to seedlings and young plants as well as more mature plants. It is made by composting leaves of various sorts in a covered bin composter (such as an 80 litre plastic dustbin), which is kept moist by the periodic addition of water from above. In this case the liquor which drains through the composting leaves is directed to a liquor catching tray and retained and can then be applied to seedlings and more mature plants as a plant food. The liquor has the appearance of tea.



On the left photo the leaf compost liquid plant food maker can be seen next to a leaf mould basket covered with a plastic sheet to retain moisture. The liquor catching tray can be seen with the jug inside it. On the right the liquor catching tray and the inverted metal dust bin lid can be seen more clearly.

It has already been seen that composting leaves have a high content of valuable nutrients suitable for plant growth. The range and nutrient content of the leaf compost can be improved further by adding comfrey leaves which contain a wide range of nutrients including a high content of potassium, which is valuable for plants like tomato, potato and onion. Worms may develop naturally in such a composting pile, and if not can be added artificially. They flourish. So the resulting compost mix contains not only nutrients derived from composting leaves, but also from the worm castings which are also rich in valuable nutrients. Water is added every few days to the mix and the resultant liquor collected. When water is passed through this mix it picks up a valuable range of plant nutrients. The liquor can be used neat or diluted with water on plants with beneficial effects. After some months the leaf composted can be harvested from the composter and recharged with fresh leaves. The harvested material can be used as a mulch or mixed with other soils before planting vegetables.

The leaf compost liquor maker is filled with semi composted leaves taken from the leaf composter basket and extra comfrey leaves are added (right). Worms can also be added. Those flourishing in this system were not added deliberately, they were already present in the leaf compost. In this case the composted leaves are mainly bougainvillia. Thin layers of soil can also be added.

Five litres of water (from a pond in this case) is added to the top of the composting leaves. This drains down though the mix of leaves and worms. On the right healthy worms living in the leaf compost.

On the left photo spinach seedlings on the right basins have been fed with the leaf compost liquor and are growing more vigorously than the water fed seedlings in the left basin. On the right photo, healthy spinach have been grown in basins by the combined use of diluted urine (2 treatments of 3:1) and the remaining 6 treatments (2 per week) of leaf compost liquor. The liquor contains less nitrogen than urine, but more minerals of other sorts. The crop was more healthy, than similar crops fed with diluted urine alone.

The leaf compost liquor is also excellent for feeding seedlings and can be used undiluted. Here seedling tomatoes which have grown from compost are transplanted into seed trays. They are transferred again to buckets to grow to full maturity. The leaf liquor can also be used to feed the larger tomatoes. The humus formed from human manure invariably contains tomato seeds which germinate when watered.

4. A worm farm

The writer has made excellent potting soil which is rich in nutrients by farming worms in manure and leaf mould, using leaves placed on the surface as a worm food. Small red worms are used, but in general most worms will do. The technique involved cutting a 200 litre steel drum in half (various other containers, sometimes known as "worm bins" can also be used) and using these to make the "worm farm."

Holes are made in the base of the drum for drainage. The drum with the open side up, is mounted on three bricks to raise it above ground level. These bricks, surrounded by wood ash, help to reduce the nuisance from ants. A layer of river sand 50mm thick is added to the base of the drum. Then a layer of manure (in this case goat manure) is added about 75mm deep, followed by some leaf mould. Then a hand-full of worms are added. Further layers of manure and leaf mould are added followed by more worms. This layering is continued until the drum is nearly full. Finally the manure is covered with a mix of fertile soil and leaves. The leaves act as food for the worms and more leaves are added to the top of the pile from time to time. The drum is watered down and kept moist from time to time. It should never be flooded with water.

In a few months the worms will have turning the manure and leaves into rich potting soil. They will also have multiplied and new small worms will start to grow. The worms take the leaves down into the manure which turns into a rich and valuable potting soil. The potting soil can be removed in small amounts from time to time as it is required. The worms can also be harvested and used to seed more worm farms.

The earth worm is nature's farmer. Earthworms are tireless workers turning over the soil, and taking down fresh vegetable matter, such as leaves, from the surface, down into the soil. The burrowing of the worms aerates the soil and the worm's faeces (worm castings) are also very rich in nutrients. Where earthworms are present in the soil, you can be sure that the soil is good and fertile.

Worms are Nature's gardeners

The well researched and widely used art of farming worms to increase soil fertility, known as vermiculture, and its used in ecological sanitation, has been described in many books and magazines. Perhaps the best known is the Worm Digest (email : mail@wormdigest.org). A comprehensive list of sources of information is available in the Sanitation Promotion Kit (WHO – 1997 see bibliography).

5. Modifying urine as a liquid plant feed.

As we have seen urine is an excellent plant food rich in nitrogen and is particularly valuable for maize and green leafy vegetables. The technique of diluting with water in ratio's of 3:1 or 5:1 and applying to maize and vegetables once or twice a week can produce very positive results. But care is required because of the high ratio of nitrogen compared to other major nutrients. If over applied, urine can be toxic to plants and is quite capable of slowing down plant growth as well as accelerating it, if the urine is applied in too concentrated a form or when the seedlings are still young. For instance if young tomato seedlings are planted in potting soil and watered just with water only, the growth will be good. If a 3:1 mix of water and urine is applied to the seedling which are too young, the growth may become stunted.

However it is possible to manipulate the urine to increase the proportion of phosphorus in relation to nitrogen – a technique which may be useful for young seedlings. One technique which as promise, but still needs more investigation is to sediment out the *struvite* (the mix of phosphorus salts contained in urine) and then dilute these with water. When shaken the sediments rise up in the water and can then be applied as a liquid feed for young tomato.

A technique which I have tried with some success is to add banana skins to the raw urine in bottles and then allow the sediment to form. These skins are high in phosphorus and may help to promote the sedimentation, but I have no proof for this. A second, taller bottle is prepared and a small plastic pipe introduced in the side wall one 6^{th} of the way up. This is stoppered or bent to close it off. The urine from the holding bottle is then shaken up to release sediment and poured into the tall bottle and allowed to sediment over a few days. The top $5/6^{th}$ of the urine is then drained off through the pipe and can be used as a nitrogen liquid feed, diluted with water. The tall bottle is then topped up with water and shaken, making a mix which contains more phosphorus and less nitrogen than the original urine. This is shaken up before applying to the soil. I have found this concoction helps the tomato seedlings a lot. However the phosphorus in *struvite* is released slowly and its effects are felt over a period of time. The proportion of phosphorus can be increased further by repeating the process.

The covo seedlings on the upper layer have been given the *struvite* mix as described above. Those covo below have been given water only. An increase in growth of the seedlings can be seen. This may be due to the higher proportion of phosphorus in the *struvite* mix and the greater dilution with water (5:1). compared to the normal diluted urine, (3:1) which can stunt very young seedlings.

Once the seedling is well established and during the later vegetative stage of growth, the 3:1 water/urine mix can be applied to the plants (leafy vegetable) once or twice a week. In Mexico, a small hand full of humus is applied to the raw urine and allowed to ferment. This is also reputed to enhance the properties of the urine as a liquid plant food. It seems there are many ways of manipulating and diluting urine, so it becomes more effective as a plant food. It is also possible to add some single super phosphate fertiliser to the diluted urine mix, about 10 gms per litre of a 3.1 or 5:1 mix of water and urine. This will increase the ratio of phosphorus, with positive results. Also wood ash can be added to this mix (also about 10gms per litre of a 3.1 or 5:1 mix of water and urine. This will increase the proportion of potassium, which is good for fruiting vegetables like tomato. In practice a teaspoonful of single super phosphate fertiliser can be added to 0.5litres of a 3:1 or 5:1 mix of water and urine and applied once a week to 10 litre containers. This is useful earlier on in that plants growth. Later on wood ash (to provide potassium) can be applied with the diluted urine. In practice a tablespoonful of dry wood ash can be added to 0.5litres of a 3:1 or 5:1 mix of water and urine and applied once a week to 10 litre. Wood ash and other sources of potassium are particularly good for tomatoes.

6. The usefulness of mulch

Mulch is name for material like leaves or leaf compost which are placed over the soil's surface where plants are growing.. The advantages of mulch are many. These include reducing water loss from the soil's surface, protecting the soil's surface from baking hard after watering in direct sun, thus increasing aeration, also weed formation is reduced, so the competition for nutrients is reduced - the planted vegetable gaining what the soil can provide. Also the variation on surface soil temperature is reduced and is more moderate – an important factor in hot climates – reducing stress on plants. But one of the most valuable properties of mulch is the extra nutrients it can provide. We have seen how many nutrients there are in leaf compost, and when this material is applied to the surface, the rain or watering will slowly release these nutrients into the soil beneath for plant use. The same applies to leaves which will remain moist in an environment where the plants are being regularly watered. The use of comfrey leaves is a good example. These are cut up and applied to the soil surface around the plant and slowly release their valuable nutrients into the soil for plant use. Comfrey leaves are rich in many nutrients, notably potassium, so mulching tomato with comfrey leaves can work wonders for the crop. The leaves are placed over the soil around the plant, once the soil's surface has been loosened to help aeration. Mulching is a simple but most effective technique.

The soil in this 10 litre basins of onions have been covered with leaf mulch. The mulch helps in many ways. It conserves water, adds nutrients and reduces weeds. Well worth the effort of applying.

17. Some special constructional techniques related to eco-san activities

Several techniques have been described in this book which support the practice of ecological sanitation. Eco-san is partly concerned with building toilet structures and partly with recycling the humus and urine to grow vegetables and other plants. The details of latrine construction and methods of applying the humus and urine to improve crop production have already been described. What remains is a brief description of some allied constructional techniques which are valuable in supporting the practice of ecological sanitation. These include the construction of cement jars in which humus can be formed from human excreta and also cement basins in which plants can be grown. It also includes various low cost pedestals, both urine diverting and non urine diverting. Also low cost ventilation pipes for latrines and hand washing devices. None of these have so far been described in this book.

Making cement jars and basins

The most economical method of making containers that will last year after year (if treated carefully) and be recharged many times is to use off-the-shelf buckets or basins as a mould and caste replicates in concrete. The concrete containers are heavier than the plastic bucket or basin, and thus more cumbersome to move, but in the long term they are very durable, being made of concrete, particularly if they are well made and cured and cared for. Split cement jars can be made of 30 or 80 litre capacity and a good concrete basin of 10 litres capacity. The best shape for growing shallow rooted vegetables (lettuce, spinach, rape, covo, onion)is broader and not so deep, so the concrete basin of 10 litres capacity is possibly best and most economical. The ten litre basin about 38cm in diameter and 14cm deep serves this ideally. Up to 50 ten litre concrete basins, can be moulded from a single bag of cement and river sand. Each basin will contain 2 or 3 rape or spinach plants, 1 or 2 tomato plants or 5 – 10 onion plants. This is quite an economical way of containing precious eco-humus and using it efficiently for vegetable growth. Maize can also be grown on shallow basins of this type.

1. Making 10 litre cement basins for vegetable growing.

This method is very simple and effective. The ingredients are river sand and cement. The mould is a standard 10 litre plastic basin. The mixture is 3.5 parts river sand to 1 part cement, using a pea tin container as a measuring device (400ml containing 500 gms cement). Two tins of cement (1 kg) are mixed with 7 tins of sand and water is added to form a moderately stiff but workable mix. The mix can be made in a separate basin. A piece of plastic sheet (plastic bag) is cut into the shape of the base of the basin and laid down within the basin. The cement is spread and drawn up the inner sides of the basin using hands and trowel. A layer is also trowelled evenly over the base. The cement mix is spread out evenly. Several of these can be made at one sitting depending on the number of basins available. Six is a good number and can be made in less than one hour. The concrete work is covered with a plastic sheet and left overnight. The following morning the concrete is watered and left under the plastic sheet for another 24 hours. The following morning the basins are turned over, exposing the base, and laid in the sun. This heats the plastic, which expands and the plastic basin mould can easily be lifted off the concrete replica. The concrete basins are then immersed in water or kept wet under plastic for several more days - the longer the better - to gain strength. Once cured three or more 8 - 10mm holes can be drilled in the base with a masonry drill for drainage. With care nails and hammer can also be used to make holes. The concrete basin is now thoroughly washed down and is now ready for filling with a suitable growing medium.

On the left six plastic basins are lined up ready to have the concrete mix added. A disc of plastic sheet has been added to each basin to ease the extraction of the cement basin later. On the right the mix has been made up (2 parts cement, 7 parts river sand and 2 parts water – made into a stiff mix). The mix is trowelled on the base and up the sides and smoothed down. It is then cured over a period of days.

2. Making a 30 litre split cement jar for excreta processing or vegetable growing

Where a family is using a urine diverting toilet and processing its faecal matter into humus held temporarily in buckets (see ***Skyloo***), the 30 litre split cement jar is a very good option as a "secondary processing site". The section below describes how a cement jar can be made in two halves (shells) so that it can be used to contain the combination of faeces, paper, wood ash and soil from the toilet - it can also be used to grow vegetables.

A 30 litre plastic bucket is carefully cut exactly in half with a hacksaw blade along a line marked on the bucket. The bottom surface and the top rim are retained to keep the shape of the bucket. In addition it is useful to cut a wooden spacer and attach to the top rim of both halves of the bucket to ensure that the rim keeps its shape. It is best that the two halves cast in concrete on the bucket mould keep their shape and match each other when fitted together. Once cut in half the bucket handle mounts are cut off and trimmed. The outer surfaces of the bucket are then sanded down to roughen the surface slightly. A layer of grease or thick oil is then applied to the outer surface. The concrete mix is then prepared. This is a mixture of river sand (3 parts) and cement (1part). A small tin (volume 450mls) containing about 500 gms of cement can be used as a measure. 15 tins of sand and 5 tins of cement are used for each split jar (2 pieces). The cement is applied to a thickness of one cm and smoothed down.

The castings are allowed to set overnight and the following morning they are watered and placed under a sack or plastic sheet. They are kept wet for another 5 days mounted on the moulds. Then they are carefully separated from the moulds to provide two halves. The longer cement is kept wet, the stronger the jar will become. It is best to immerse them in water for another week. The moulds are cleaned down and coated with another layer of grease to make another set of castings. About 18 split cement jars can be made with a single bag of cement. Cement when properly cured is a very strong and long lasting material and a makes a very valuable container.

Plastering the two shells of the 30 litre split cement jar on a mould made from a 30 litre plastic bucket. After a few days of curing the two cement shells can be separated from the mould.

Making the lid

The same mixture (3:1) is used to make the lid. This will require about 3 tins of sand and 1 of cement). A 15 litre plastic bucket is toped up with soil and a sheet of plastic paper is cut and placed on the soil. The cement mix is then added to the top surface about 1.5cm deep and a handle (such as a steel chain link) is set in a raised section in the middle. Only 1 or 2 lids are required, as only one will be filling at one time. The rest will be holding plants or will be empty. Lids are required to protect the excreta from flies and animals.

Assembling

The two shells are then placed on the ground together in a suitable place in the garden, possibly in a flower bed. They are then wired together to make the shape of the container. In this case the container is erected so that the broader base is at the bottom. This allows for good drainage from the container. The additions of soil and excreta are then made over some days or weeks. These may be the contents from buckets containing excreta coming from the urine separating toilets or even dog/animal manure. Layers of soil are added between the additions of excreta as the layers build up. The lid is kept in place at all timed when the fresh material is being built up. Good drainage is important on containers holding fresh excreta and soil.

30 litre split cement jars are ideal for processing faeces. The two shells are held together with wire. A lid is made to fit over the jar. Painting makes the jar more decorative.

3. The 80 litre split cement jar

This is made in a similar way to the smaller jar but on a bigger scale. An 80 litre plastic dustbin can be used as a mould. The handles of the dustbin are cut off and the outer surface smoothed down. The bin is carefully marked and cut in half with a saw. The same process is followed as for the 30 litre jar. A thin layer of grease or oil is applied to the outer surface and the mix of river sand and cement made up. The mix is 3 parts river sand and one part cement. In this case 18 (450 ml) tins of sand are mixed with 6 tins of cement for each of the two shells made. The mortar is built up to 15 - 20mm thickness. The curing, removal and further curing are carried out in the same way as for the smaller jar. It is important to allow sufficient time for the cement to cure by keeping it wet for several days under plastic sheet. Once fully cured the two shells are carefully separated from the mould and then wired together with the wider end at the base. A cement lid should also be made to fit the jar. This jar makes an excellent container for composting manure of several types. If four are made, the processed manure, together with kitchen wastes can be used in sequence continuously, with one being filled with another two processing and the fourth reaching a stage where it can be emptied.

Making the larger 80 litre split cement jar using a plastic dustbin as a mould.

Four 80 litre jars were made and used in rotation to process compost from kitchen wastes and manure

Low cost toilet pedestals

There are several ways of making low cost pedestals for use in toilets. In each of the methods described here a plastic bucket is used as a mould and insert for the pedestal. That is the pedestal is built up around in the bucket in cement, which acts as a mould, but also the bucket is left in place to provide a smooth surface inside the pedestal which can be cleaned down.

1. Very low cost pedestal

There is a pedestal which can be made cheaply from a 10 litre bucket. In this case the base of the ten litre bucket is sawn off and laid wide end down on a sheet of plastic. A line is drawn around the base rim of the bucket about 75mm out. Some strong cement mortar is now made 2 parts river sand and one part cement. This is built up along the inside along the line drawn on the plastic and up the side walls of the bucket. With care this can be done in one sitting. This is left to cure for two nights and then the bucket and its concrete surround is lifted up and turned into a base mould made of wood measuring about 40cm X 40cm. The base is cast in 3:1 sand and cement and left to cure. The seat is formed by the rim of concrete laid around the bucket on the plastic. It can be shaped and smoothed down with sand paper and once it is dry painted with an enamel paint. This is really a low cost but practical method of making a pedestal with easy to wash down plastic insert.


Very low cost pedestal made from a ten litre plastic bucket and cement only. It is durable and with suitable painting can be made very smart.

2. Low cost pedestal with concrete seat

This method uses a 20 litre bucket - and to reduce cost - a seat made of concrete. In this case a mould is first made in concrete for the seat. This is made by mixing cement and river sand (about 1:3) and building up a "slab" about 50 mm deep inside some bricks (dimensions about 50cm X 60cm). The commercially made plastic seat is then pressed into the cement and held down with a weight. It is left there until the concrete is stiff and then the plastic seat can be removed, leaving an impression of the seat. This should be done with care. It may be necessary to finish off the mould with a small trowel to get it smooth. The mould is left to cure for a week, being kept wet at all times. Once cured and dry, it is smoothed down with sand paper. Then it can be used to make more concrete seats. These are made by taking very thin plastic sheets and covering the seat part of the mould. A very strong mix of river sand and cement (2:1) is then used to fill the depression to make the seat.

The toilet seat mould is covered with very thin plastic sheet and a layer of high strength concrete is laid in the depression which will form the toilet seat. A loop of wire is laid within the concrete. After levelling off, L shaped wires are then inserted into the concrete. An upturned plastic bucket (with base removed) is then placed over the mould with the wire arranged around the outside of the bucket as shown above. Cement is then built up around the sides of the bucket. The wires strengthen the cement work.

A loop of wire is introduced to provide strength. L shaped wire inserts are now placed in concrete to strengthen the link between the seat and the side walls of the pedestal. This is done by laying the wider end of the 20 litre bucket (with the base already sawn off) on the seat. L shaped pieces of wire are then introduced into the cement around the rim of the bucket. The bucket can be left in place whilst the seat cures. Next a layer of strong cement mortar (2 parts river sand and one part cement) is built up around the bucket till it reaches the top. This is left to cure overnight and some thin wire is wrapped around the cement work (in a spiral form) and another layer of cement is applied. This is left to cure for another day or two, then the seat and the side walls of the pedestal can be removed. The pedestal (right way up) is then mounted within a wooden base mould (dimensions - outer 50cm X 50 cm - inner 40 cm X 40 cm) and the space between the wooden mould and the side walls of the pedestal are now filled with a 3:1 mix of river sand and cement with some wire reinforcing. This left to cure for another few days being kept wet at all times. Once cured and washed down, the pedestal seat can be sanded down and any small holes filled with neat cement slurry (nil) and then allowed to dry. The pedestal is then painted with an enamel paint and put to use by cementing in place within the latrine.

Very low cost and durable pedestals can be made with off-the-shelf plastic buckets and cement. With care and paint they can be made into very attractive units.

3. Low cost pedestal with plastic seat

This is easier to make and smarter, but more expensive. A commercially made plastic toilet seat is required. First holes are made with a hot wire in the supporting plastic ribs under the seat, so that a ring of wire can be threaded through under the seat. The “hollow” under the plastic seat can then be filled with a strong 2:1 river sand/cement mix with the wire inside. At the same time the 20 litre bucket (with base sawn off) is placed over the seat in a central position and L shaped pieces of wire inserted around the rim of the bucket into the cement. This is left to cure for a few hours. Then the side walls of the bucket can be covered with a 2:1 sand/cement mix. This is left to harden a little. Later some thin wire is laid spirally up the side walls of the pedestal to strengthen the unit. A further layer of mortar is then applied to the side walls. This is left to cure, being kept wet at all times. The pedestal is then overturned into a base mould made of wood, and the base made with more strong concrete - and left to cure. This procedure makes a neat, comfortable and long lasting pedestal.

Sequence of making pedestal

Finally a strong durable pedestal is made

4. Home made urine diverting squat plate

Squatting is the preferred position for defecation over much of Africa. It therefore makes sense to use a squatting type urine diverting device, if urine diversion is the chosen method of taking up ecological sanitation. The urine diverting squat plate is used almost universally in China and commercially made units are also available in Kenya. A home made copy of this effective unit can be made using off-the-shelf buckets and cement.


Make a mould in wood to make a small concrete slab 60 cm long by 30cm wide. Before pouring concrete cut a ten litre bucket, using the lower part to make rear squat hole, 20 cm wide and the upper part of the bucket to make the front hole (about 23cm wide) for later insertion of urine receiver. The strong concrete mix can be made from 3 parts river sand and one part cement. Reinforcing wires are laid in the cement for additional strength. This is left to cure for a few days, being kept wet after the concrete has set.


To make the urine receiver, take another 10 litre bucket and drill hole in lower end and attach a small 20mm plastic pipe fitting. This can be attached by welding the plastic or by using an epoxy adhesive. The bucket is cut so the upper edge at the front is higher than the rear. The rear edge should be at slab level.

Before the bucket is finally cut, it is inserted in the front hole of the slab and tilted so all urine will drain into the urine exist hole and the forward part of the bucket is higher. The bucket is marked and cut ands then placed in the hole and strong cement mortar is laid all around the bucket on top and beneath. This is also allowed to set and cure.

1. **After curing the unit is allowed to dry and is painted with an enamel paint. Note the side view of the unit on the left photo. See how the front of the urine collector is raised and the rear is low allowing good drainage of urine into the urine pipe. A raised front end catches urine better. The great advantage of the urine diversion squat plate is that males can urinate whilst standing above the unit. This offers a larger target for urine compared to most urine diverting pedestals. It is important however that males urinate in the correct hole. The urine diverting squat plate is fitted over a concrete slab in which a rectangular hole of suitable size has been made. Cement work does absorb urine, so the cement parts should be well protected with enamel paint.**

5. Home made urine diverting pedestals

This can be an adaptation of the pedestals which have been described earlier in which a urine diverter, made from a plastic bucket, is inserted in the front part of the chute of the pedestal. This urine diverter can be attached to the main bucket of the home made pedestal by welding, gluing, bolting or by wiring.

There are many ways of doing this, the main aim being to catch and divert as much urine as possible so it can be piped to a plastic storage container. The faeces can then drop into the vault below.

In this method a piece of plastic from a bucket is bolted to the side wall of the larger chute bucket to make the urine diverter. At the base of the diverter a polyethylene pipe is fitted in place with epoxy putty. Urine passes down the diverter, through the pipe into the urine storage vessel. This plastic unit is then built up in cement and a seat is fitted as described earlier.

In this method the urine diverter (yellow) is made from a 10 litre bucket and fitted inside the larger chute bucket (25 litre) with wire straps. These wires pass through the plastic and later cement work. The rest of the pedestal is then built up as described earlier. A plastic pipe fitting is then attached to the yellow bucket to lead the collected urine into a urine storage vessel.

On the left the completed urine diverter fitted to a Skyloo. The bucket which collects the faeces, soil and ash can be seen directly beneath the pedestal. On the right a home made urine diverting pedestal made in Kenya.


Once again a 10 litre bucket is cut to shape as shown to make a urine diverter which can fit into a standard (non urine diverting) pedestal as described earlier. A urine outlet pipe is fitted through a hole made in the bottom of the urine diverting bucket. When fitted on to the pedestal, the bottom of the urine bucket is sloped so that urine drains towards the outlet pipe. On the right the wire loops formed in the pedestal to hold the urine diverter. These can be fitted when the pedestal is being made or threaded through holes drilled later through the bucket and cement work.


A side view with the pedestal upside down showing how the lower part of the urine diverter slopes downwards so that urine will drain into the pipe. The lower part of the urine diverter must be able to pass through the hole made for the pedestal in the slab in such a way that the pedestal itself sits on top of the slab. The part of the diverter which holds urine before it drains through the pipe is actually held underneath the slab. On the right the finished urine diverting pedestal.

Method of making a urine diverting pedestal with urine pipe above slab level

Normally the urine diverting pedestal directs urine into a pipe which is held beneath the toilet slab or floor. In this way the pipe is protected and is able to safely lead the urine either to a soak pit, into a garden or a urine collecting chamber made of plastic. Great care is required to ensure that the pipe allows urine to flow freely downwards to avoid air locks occurring in the pipe, as these can cause problems with the free flow of urine from the diverter to the collector. When a double vault system is used, care is required in disconnecting the urine pipe linked to one vault with the urine pipe of the second vault.

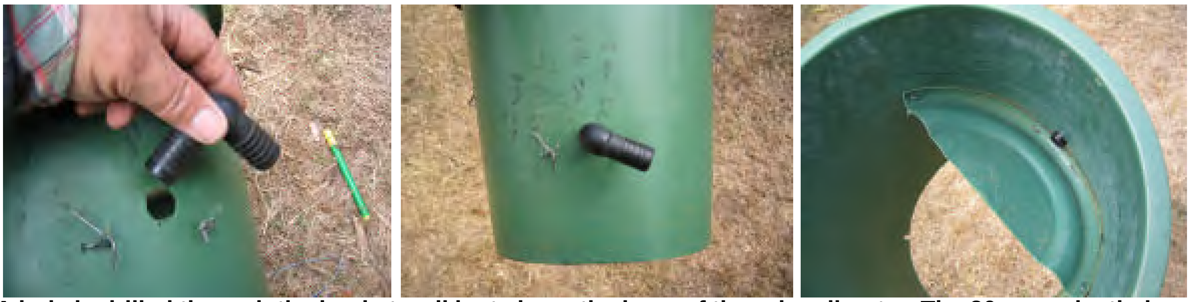
These problems can partly be overcomes by making a urine diverting pedestal where the urine outlet pipe is placed above the floor or slab level. Thus it is possible to connect a pipe directly to a fitting on the pedestal and lead the pipe away and to the rear above ground. This method is particularly suitable where the urine diverting pedestal is placed over a shallow pit toilet. Once the pedestal is fitted on top of the toilet slab, the urine pipe can be led away to the rear of the toilet and direct urine either into a a seepage area around a tree, or vegetable garden or into a urine container which can be dug in a shallow hole below ground level.

Sequence of making a urine diverting pedestal with urine outlet pipe above slab level

The material requirements are a 20 litre plastic bucket, a 20mm polyethylene bend, a plastic toilet seat and cement, sand and wire. First the base is sawn off the bucket squarely.

Next the plastic base of the bucket is sawn in two, one of these halves will be used to make the urine diverter within the bucket.

The half base is fitted within the bucket about half way up the walls at an angle. It is secured in place by drilling small holes through cut base and bucket walls and passing wire through and tightening.



A hole is drilled through the bucket wall just above the base of the urine diverter. The 20mm polyethylene bend is fitted through the hole as shown. It is placed at the angle shown above.

The toilet seat is now prepared. Using a hot wire, holes are drilled through the plastic ribs which support the seat. These allow a wire to be threaded in a loop under the seat.

A strong mix of concrete using 3 parts river sand and 1 part cement is mixed and added to the toilet seat as shown. This will add strength to the seat and form a bond between the seat and side walls of the pedestal. The bucket is now fitted centrally over the toilet seat as shown.

8 pieces of bent wire are now introduced into the cement supporting the seat. This is allowed to cure overnight. Next a further mix of 3:1 sand and cement is made and plastered half way up the walls of the bucket. This is left overnight again to cure.


The following morning the upper half of the bucket is cemented with a 3:1 mix and allowed to cure overnight. The next morning the bucket and seat are overturned into a base mould made with wood, about 60cm X 60sm and 40mm deep. It is laid over a plastic sheet.


The base mould is filled with the same 3:1 river sand/cement mix. Some wire is added to the base. Also some thin wire is also coiled around the pedestal. Next a final later of 3:1 mix is plastered up the side walls of the pedestal over the wire. The final layer can be made with cement watered down to make a thick paint and is applied with a brush. This is allowed to cure for several days being kept wet at all times. It is covered with plastic sheet and sacking.


The space between the bucket side wall and urine diverter is now sealed. Any type of pliable putty can be used for this job. Even chewing gum will do. It is pressed into the gap from underneath first. The putty should also be pressed into the gap from the upper side too. Urine passing into the urine diverter should find its way through the plastic bend and through the plastic pipe.

The urine outlet pipe has been added to the polyethylene pipe bend. This is led back over the concrete base of the urine diverting pedestal to the rear of the toilet.

The pedestal can be made more attractive by coating with enamel paint once the concrete is completely cured and dry. Once dry it can be mounted into the toilet.

The urine diverting pedestal can be fitted into a single or double vault dehydrating or composting toilet. It can also be fitted over a shallow pit toilet. The urine pipe can be led into a soakaway or into a vegetable garden, preferably beneath ground level. It can also be led to a tree like a banana, as shown above. The urine can also be led to a plastic container placed in a hole dug in the ground. It is advisable to protect the pipe in some way by covering with soil etc. Here the pipe is exposed for the photo.

Final note on this method

Where the urine is led through the pipe to a tree or vegetable garden, it is possible to add more water through the urine diverter to cleanse the pipe and dilute the urine. When the diverter is used over a shallow pit toilet, it is advisable to add soil and ash to cover the deposit to encourage dehydration. If composting is required in the pit, as in the ***Fossa alterna***, the pit contents must be moistened by adding urine or water, with soil and ash and preferably leaves.

6. Home made vent pipes.

A vent pipe is a valuable part of any pit toilet. It draws out air from the pit, mostly by the action of wind blowing across the top of the pipe. The air that flows out of the pipe is replaced by air passing down the squat hole or pedestal. This is most efficient when the slab and pit collar are sealed and airtight. The effect is that any foul odour from the pit does not escape into the structure, but is diluted by air and passes out of the pipe into the atmosphere. The effect is that the toilet becomes almost odourless. The other property of note is that, if the top of the pipe is screened with a corrosion resistant screen made of aluminium or stainless steel, and the structure is fitted with a roof, the pipe also acts as a flytrap. Where the interior of the toilet is semi dark, flies will enter the pipe from inside and are trapped. This is because flies are attracted to light when they leave the pit and enter the pipe which is the most obvious light source. From the outside, flies are attracted by odours coming from the pit and most of these are expelled through the head of the vent. If the head of the pipe is screened, they cannot enter the pit. This simple effect can dramatically reduce fly breeding in the pit toilet and thus reduce the passage of fly-born disease. So the vent helps to reduce fly breeding and odour. Toilets fitted with a vent are generally known as VIP's (ventilated pit latrines). There are over half a million in Zimbabwe alone.

Even on shallow pit eco-toilets like the ***Arborloo*** and ***Fossa alterna***, venting helps. Whilst the addition of plenty of ash and soil, helps to reduce odours and the potential for fly breeding considerably, the action of the pipe also helps to remove excess moisture from the pit chamber, as well as removing odours and reducing fly breeding. Vent pipes can be made from bricks, steel, asbestos and PVC. Asbestos is more durable than PVC, and the most efficient are smooth walled round pipes, asbestos and PVC being the most common. 110mm is a minimum acceptable vent diameter, although 90mm may just pass for eco-toilets which already have some degree of fly and odour protection from the regular addition of soil and ash. Commercial pipes are very expensive, but there are ways and means of making then at the homestead.

Several methods are available, one being the use of hessian cloth (sacking) soaked in a mix of cement and sand (ratio 1:1). The cloth absorbs the cement slurry which is best cut into strips about10cm across. The slurry filled strips are then wrapped around a suitable mould. This can be made of a wire or reed tube or even a bundle of grass suitably wrapped. Alternatively a PVC tube can be used as a mould to make many cement pipes. In this case the PVC tube is covered with plastic sheet and the hessian strips wrapped around it and spiralled up the tube. Four length of thin wire (about 2 – 3mm thick) are then placed down the length of the pipe and held in place with thinner wire. Then the strips of cement filled hessian are then wound spirally back down the pipe again with strips overlapping. The final layer is painted with the slurry using a brush. It is left to set overnight and then made wet in the morning and covered with plastic sheet. The pipe is kept wet for at least 7 days before it is moved. The PVC pipe is then twisted out of the cement pipe and the plastic sheet extracted. A suitable screen is then fitted by wrapping around the head of the pipe and fixing with wire. Plain steel screens corrode quickly and are of little value in fly control. Aluminium screen is best. If well made and cured, such cement pipes are very strong and durable – far more so than PVC.

A durable home made vent pipe constructed from Hessian and a sand cement slurry with some wire reinforcing. Very effective and longlasting.

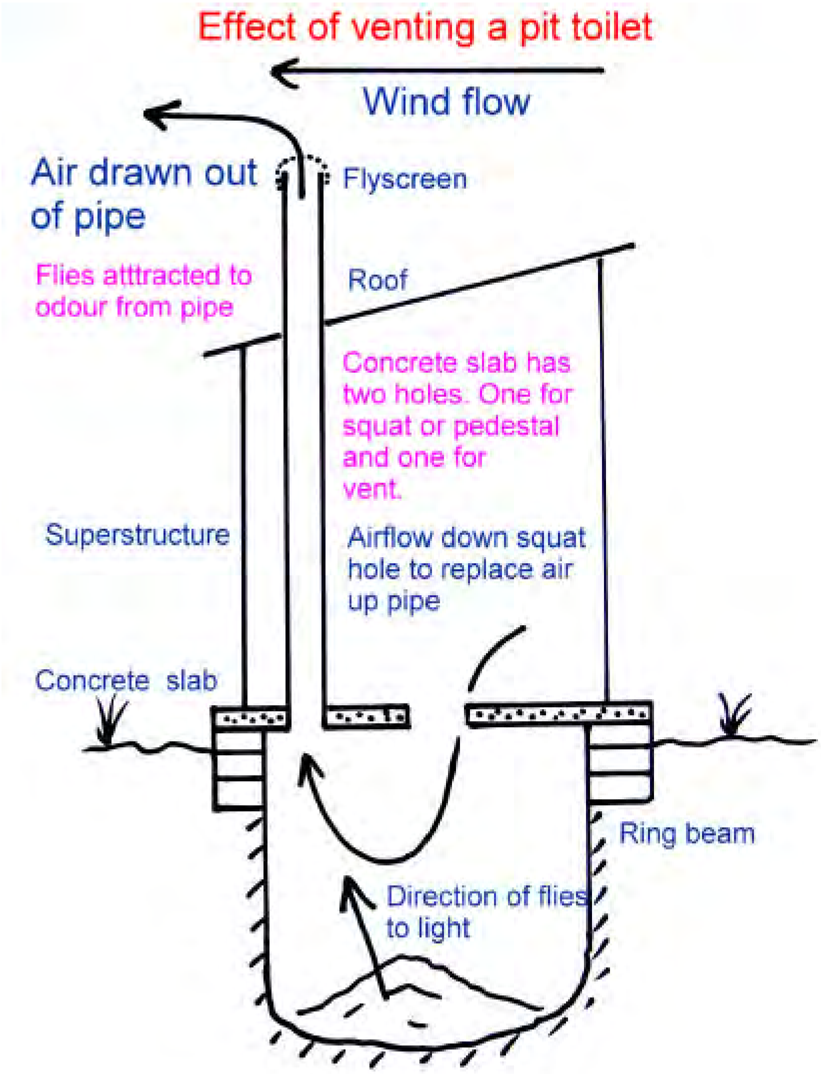


Diagram showing effect of vent pipe on functions of pit toilet

7. A steel framed superstructure for use on a range of on-site toilets

We have read in the book about the huge range of superstructures which can be used with these eco-toilets. Grass and poles through to brick, or iron sheet. All work, their primary aim is to provide privacy. One particular technique has proved itself to be particularly adaptable to a wide range of conditions and is described here. It consists of a light steel frame welded together using a combination of 25mm angle iron and 25mm flat bar. The durable hinge is made from old car tyre. The roof panel is covered with chicken wire and then a plastic sheet. Grass can be placed on top or thin iron sheet. The walling can be covered with any suitable material, which can include grass, reeds, plastic sheet, sacking or hessian, thin plywood or even wooden slats or other timbers. Whilst the frame is not particularly low cost (the steel costs around US$50 and a similar amount for labour), one made it will last afamily for many tears and can be covered with locally available materials which can be collected freely or cheaply.


Front and side views of the superstructure frame covered with grass

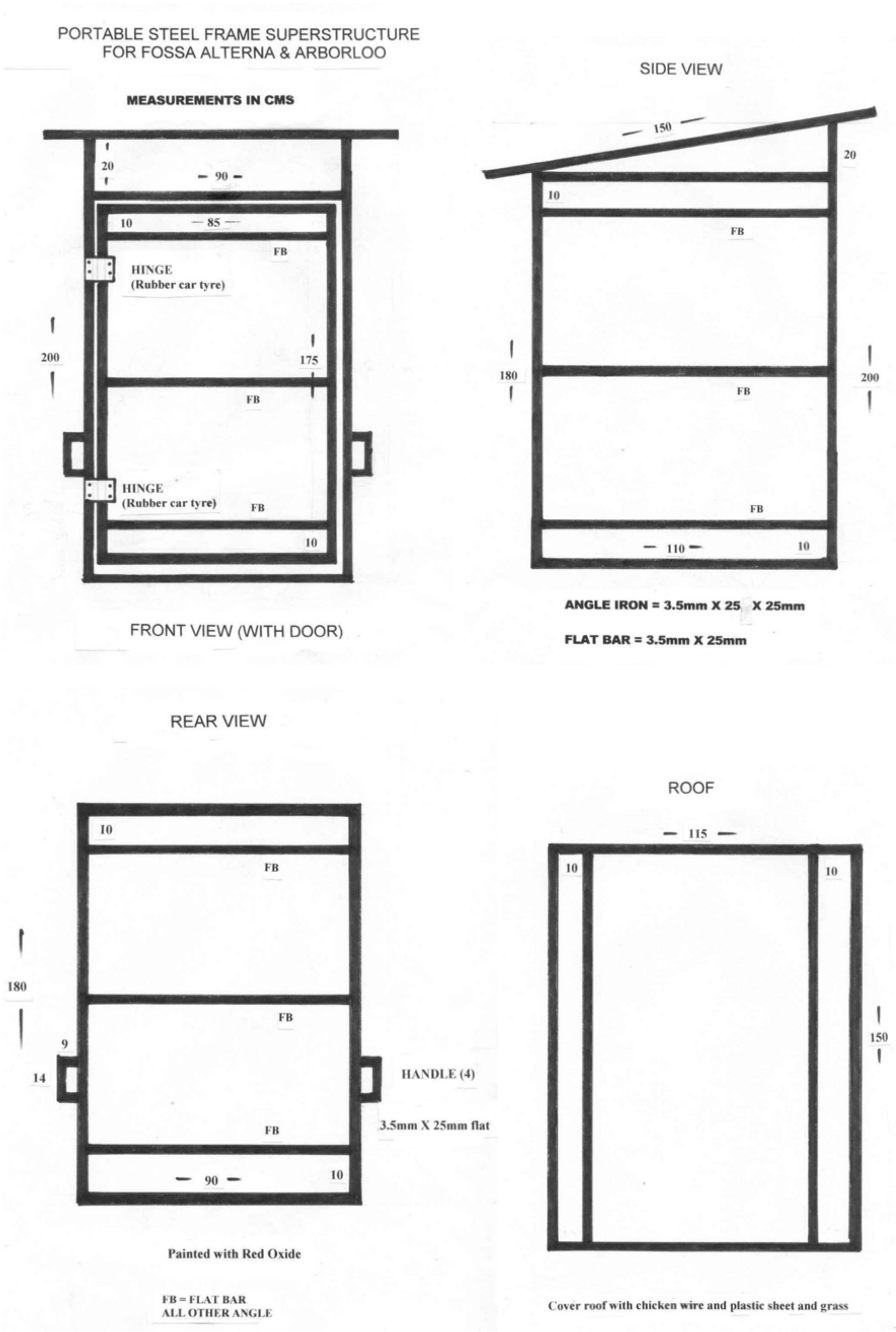

Rear view of structure and close up of carrying handle and rubber hinge

Close up of hinge and carrying handle and arrangement of steel work.

Close up of upper parts of the frame and roof

The asbestos pipe passing through the roof and a neat seat made from a bucket and concrete work only.

The frame dimensions



8. Hand washing devices

Hand washing facilities are vital if any hygienic value can be expected out of a toilet system. Hand washing is perhaps the most vital part of the process of improving personal hygiene. In fact hand washing is essential if an improved state of health is to be achieved in relation to toilet use. So all eco-toilets (and any other toilet) should be fitted with a simple hand washing device. There are several ways of making them.

8.1 Using a 5 litre plastic oil container and pill bottle.

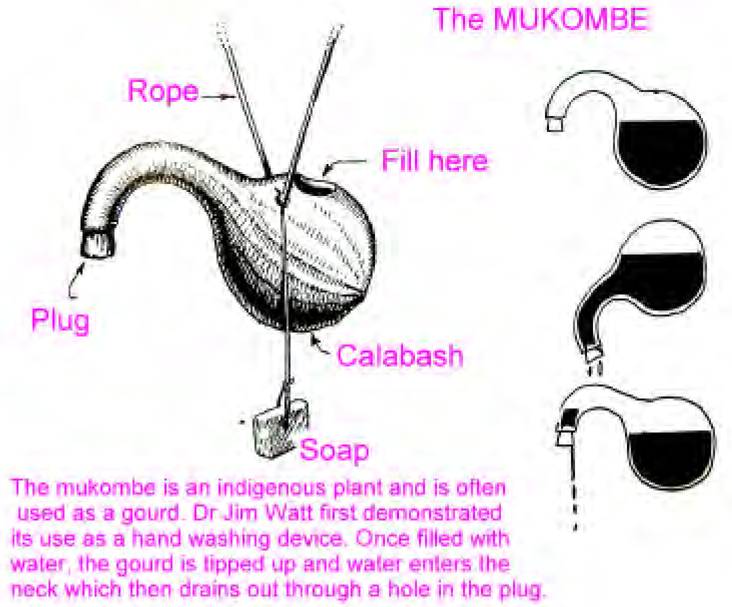
In this design a discarded pill bottle and an old 5 litre plastic oil container are used.

Hand washing device made from an old 5 litre oil container and pill bottle

The pill bottle is chosen to fit into the neck of the oil container. Cuts are made in the pill bottle lid and side wall as shown - one in the bottle cap, one in the bottle base and a 2mm hole is also drilled - see photo. The 5 litre container must be suspended on a wire or string so that it is balanced. A hole is drilled in the handle section and the container suspended on a wire placed through this hole.

The container is then thoroughly washed out and filled with water and the modified pill bottle inserted in the neck of the container. When the water container is tilted forwards, water will flow into the pill bottle through the cut made in the lid and slowly drain out of the small hole. The second opening in the pill bottle allows air out of the bottle whilst water is entering. Otherwise there would be an air lock. The small amount of water released is sufficient to wash the hands - one or two charges may be necessary. There are several variations on this theme of putting together a novel hand washing device using discarded plastic containers. Local innovation is required. There is no end to the variation of design.

8.2 The Mukombe hand washing device



8.3 The milk bottle hand washing device

Another type of hand washing device made from a milk bottle. In this case the lower part of the neck of the handle is blocked off and a small hole drilled above this level. The device hangs on a string attached to a wire passed through the bottle. When the bottle is tipped up, water enters the upper side of the handle and drains out through the hole.

8.4 Making a hand washing device from tin cans or plastic cups

This is perhaps the simplest and most elegant hand washing device and the idea originates in Malawi where it is used in both the CCAP and COMWASH ecosan programmes. It consists of no more than a plastic cup, tin can or aluminium beer can with two or three 3mm holes drilled in the base. A nail can also be used to make the holes. The cup or tin is suspended with string from either the toilet itself or from a simple wooden structure near the toilet. Water is taken from a nearby basin or bucket with a cup or scoop and poured into the device just prior to washing. Water can also be held in a plastic bottle nearby and poured into the device. A bar of soap can also be suspended nearby. Hard soap is best since a hole can be drilled through the soap and suspended on a string near the hand washing device. This simple hand washer can be made in minutes, costs almost nothing and can cleanse the hands of dangerous bacteria after toilet use. It should be fitted to every toilet made. In fact several should be mounted around the homestead at convenient places. It should always be used prior to eating or handling food. Regular hand washing is vital if improvements to health in water and sanitation programmes are to be effective. Remarkable that something so simple and cheap to make can be so valuable.

Simple hand washing device used in the CCAP ecosan programme in northern Malawi. No more than a suspended plastic cup. Water is carried from a nearby earthenware pot in a gourd and poured into the device. Used water falls on to plant below.

Simple hand washing device used in the COMWASH ecosan programme in southern Malawi. Discarded tins or plastic bottles can be used. Several small holes can be drilled into the base of the tin or container. Water held in a jar or pot is poured into the device with a mug.

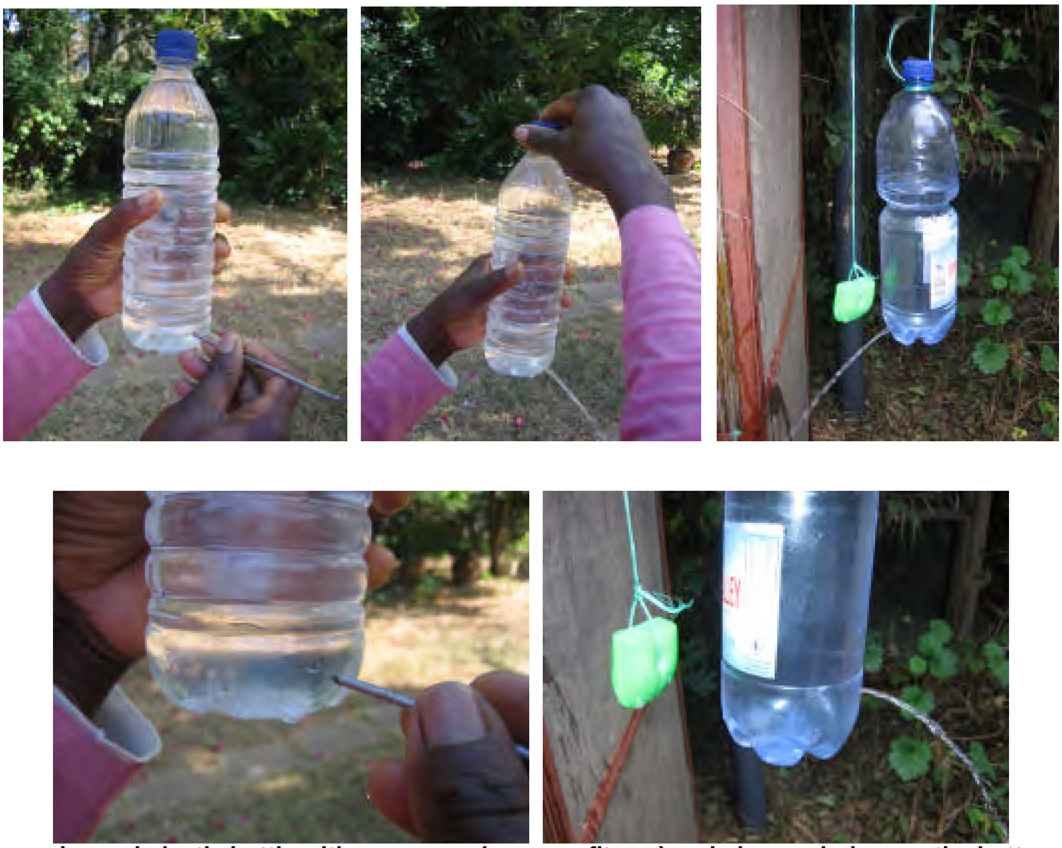
These hand washing devices, made from tins or beer cans, can be suspended directly from the toilet roof on a string as in this case. It can also be suspended by a simple wooden device near the toilet. Water can be poured into the device from a cup or from a plastic bottle. Small holes are drilled in the base of the tin or can to allow the water to drain out slowly over the hands.

Two or three 3mm holes are drilled in the upper rim for attachment to suspension strings – two holes in the base. On the right a flower pot placed directly below the washer to catch and use washing water. Two sources of water – a plastic bucket and small plastic cup and a capped plastic bottle.

Hand washing is more effective if soap is used. Here soap is suspended on a string near the hand washer

8.5 Making a hand washing device from a round plastic bottle with screw cap.

The second type of simple hand washing device is made from a round plastic bottle with screw cap. Any size will do but the larger the bottle, the more hand washes can be made before refilling is necessary. A short length of 3mm steel wire is taken and a point filed down on one end. The used bottle is filled with water and a hole pierced near the bottom with the wire. It may help to wrap some cloth around the wire to hold it firmly. The wire is pushed though the plastic and withdrawn. When the cap is screwed up water will not come out of the hole. When the cap is unscrewed water will come out of the hole, enough for hand washing. The device is hung up near the toilet. Put more in the bathroom, kitchen and eating areas.



Take a used round plastic bottle with screw cap (or press fit cap) and pierce a hole near the bottom with a pointed piece of 3mm wire. This is best done with the bottle full of water. The filled bottle is hung up on a string near the toilet. When the screw cap is closed water will not come out. When the screw cap is open water will come out and can be used to wash the hands. Soap helps.

Clean hands for Health!

The benefits of improved sanitation can never be fully realised unless personal hygiene is improved too. Regular hand washing lies at the heart of improved personal hygiene.