12. Gardening techniques that assist eco-san supported vegetable and fruit 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 techniques will also help. The production of vigorous healthy vegetables requires effort and also 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, no matter how much nutrient they may have.

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 garden compost using organic kitchen wastes, leaf compost, 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 sight 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). 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. 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 garden compost. However, it is equally well used to make leaf compost. 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 compost, 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 water and urine (about 3:1) 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 compost. 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 are 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 mixed with an equal volume of tops soil. 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 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 decompose. 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 to decompose 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 mixed with an equal volume of topsoil. 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 locks up boron. In tomatoes, pale green leaves denote a shortage of nitrogen. Small blue green leaves turning purple show 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 available, which can reduce fruiting, particularly in those plants which have a high requirement for those elements, like tomato. 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 which are not supplied by urine. Apart from garden humus and compost, liquid feeds made from manure, composting leaves 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 value of comfrey

The comfrey plant (***Symphytum officianale***) has extraordinary properties of being able to 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. One 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 provider 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 help the plants.

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 as a mulch. It is an excellent addition to the compost heap. It also has medicinal properties. On the right, cutting up comfrey and adding to water. This will ferment and provide a good plant food.

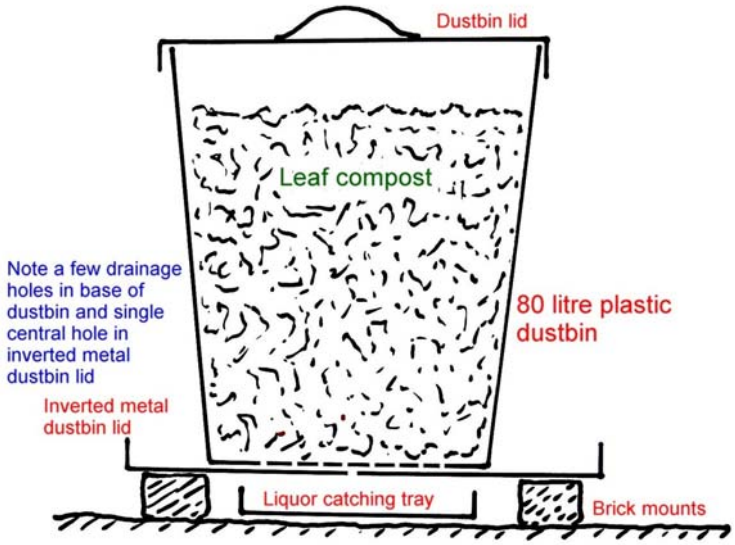
3.2 Making liquid plant food from manure

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 Nurseries 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. In eco-san we try to look for non chemical ways of providing extra nutrients.

3.3. 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.



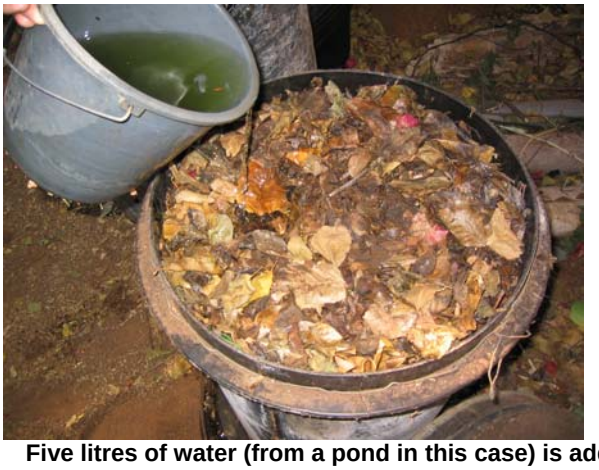
The leaf compost liquor maker

In 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.

In 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. In 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 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 turned 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 ratios 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 seedlings which are too young, the growth may become stunted.

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 has 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. In practice however the plant food derived from the leaf compost liquor maker is easier to make and use.

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 3:1or 5:1water/urine mix can be applied to the plants (leafy vegetable) once or twice a week. In Mexico, a small handful 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 plant's 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 the 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 these 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.

7. Growing tomatoes

Most of the techniques described in this chapter can help to grow good crops of tomatoes. Tomato is an important crop, but it is a sensitive plant and special attention is required to get good harvests. Very often harvests may be poor due to disease or to poor management. Tomatoes are particularly susceptible to disease during the rainy season. How can we use recycled human excreta (humus from ***Skyloo*** and ***Fossa alterna***) and our urine to get bumper crops of tomato? This process can be made easier by understanding that the young plant needs soil with a balanced mix of nutrients, but with more generous supplies of phosphorus, early on, to encourage strong root and early shoot growth. At the early stage nitrogen is not required in such quantity, although potassium which encourages the formation of fruit should also be present in adequate quantities. Too much nitrogen can block the uptake of potassium, so at first the application of nitrogen, by urine application, should be avoided. Plant food in the soil (ideally a 50/50 mix of ***Skyloo***, or ***Fossa alterna*** soil with leaf or garden compost) should be sufficient, perhaps with assistance from liquid feeds like leaf compost liquor. When commercial fertilisers are recommended at this early stage, they contain more phosphorus than other nutrients. Only when the flowers have formed and the very young tomatoes are starting to develop, should extra supplies of nitrogen and potassium be given. This can be achieved by applying a pea tin full of wood ash to the soil (about 400mls or 170gms) and digging in. Also urine can be applied to provide nitrogen. Diluted urine (5:1) can be applied at the rate of around 1 litre per week or 100mls neat per week and watered in. Thus the right food should be given at the right time. Then the plants require pruning as they grow and also staking. Regular watering also helps. Let us look at the step-by-step process that can lead to improved crops.

The right seed and seedlings

The books say that it is wise to get the right seed or seedlings first to get the best crops. Varieties called "*Moneymaker"* and "*Roma*" are known to provide good crops in Zimbabwe, and tomato seeds are generally cheap to buy, and store well. But we can also obtain good seedlings for free when the ***Skyloo i***s used, as the humus contains many seeds, which germinate when the humus is watered. Several varieties may be present. Try to avoid growing too many tomatoes when the seedlings are free and numerous. Experience shows that it is far better to grow a few tomatoes well, than a larger number poorly.

Growing tomatoes from seed

Seeds can be planted in seed trays or small pots and they germinate in about a week. They are best planted in potting soil or good crumbly fertile soil. Several seeds may germinate in a single pot and it is best to thin these out so that a single plant chosen from the group continues to grow in the single small container. These are watered regularly and can also be fed with leaf compost liquor. They should be allowed to grow in the seed tray or small pots until they are about 10cm tall. Then they are transferred into a 10, 15 or 20 litre plastic bucket (or other container) with good drainage holes drilled in the base. If small seedlings are growing in the humus derived from the ***Skyloo,*** these can also be carefully freed, together with some soil attached to the roots and transferred also into small pot or containers, where they can be fed and watered until transferral to the larger bucket (see ***Skyloo*** chapter). The best time to sow tomato seeds is between August and December, but with care they can be planted any time. If grown during the rainy season, they must be kept under cover and watered artificially.

Preparing the bucket of soil

It is important to prepare the soil carefully for the tomato bucket. It is generally best to make a mix of either ***Skyloo*** humus and garden or leaf compost or ***Fossa alterna*** humus and garden or leaf compost. It is important that fertile soil be used and it must be able to drain well. Soil processed from human excreta will contain a range of nutrients (see earlier chapter) and a good proportion of this will be phosphorus, which is ideal for the early growth of plants. Vigorous development of the root system and early shoot development above ground level depends on their being adequate supplies of phosphorus. It is the nutrients found in the soil which will carry the plant through the first two and important months of its 6 month life. The bucket is filled with the soil mix, perhaps placing a few stones in the base to help drainage.

Transplanting into buckets

When the young tomatoes are about 10cm high they can be transferred into the bucket soil and watered regularly. One plant is placed in each bucket, best late in the afternoon. Rich soil should be able to carry the plant for several weeks without any additional feeding, but as the plant grows it will benefit from the application of a mild liquid feed like leaf compost liquor. The application of urine (or nitrogen fertiliser) should not take place at this stage. The tomatoes should be placed in a sunny location but sheltered from the wind. Tomatoes also do well under shade cloth. Too much harsh sun should also be avoided. The plants should be well spaced (at least 0.5m apart) and in a place where they get plenty of air calculation. During the rainy season they must be placed under cover, and watered artificially. Avoid overcrowding and allow for adequate air circulation – otherwise fungus disease will develop. A layer of mulch, a few cm thick, made of composting leaves placed on top of the soil within the bucket will also help to retain moisture and will also provide extra nutrients.

Early application of liquid feed.

It is very important that a well balanced diet of liquid feed be given to the tomatoes. At first this can be a mild feed like leaf compost liquor, where water drains through composting leaves to form a liquid. The presence of comfrey leaves in the compost helps a great deal. Comfrey is rich in potassium which the tomatoes require for best fruiting. Urine can be used at this stage, not directly on the soil in which the tomatoes are growing, but by applying to the comfrey plants themselves. Their growth is enhanced and the leaves pick up the vital minerals from both the soil and the urine and these are later released during the composting process. The nutrients are picked up by water passing through the compost to make the liquid feed (see earlier in this chapter). The presence of worms in the compost also enriches the liquid feed. Their excreta (worm castings) is also rich in minerals. The leaf compost liquor is not strong and can be applied undiluted two or three times a week or even daily (0.5 litre per bucket), together with sufficient additional watering to keep the plants healthy. Nutrients from the soil and mild liquid feeds should be able to sustain the growth of the tomato until the flowers start to form between 4 – 6 weeks after transplanting into the bucket..

Staking

As the plant begins to grow it is wise to place a tall reed or bamboo stick (1.5 metres high) in the bucket and tie the main tomato stem to this for support as the plant grows.

Removal of side shoots (pruning) as the plant grows

As the plant grows it is wise to remove some of the lowest shoots and leaves and also those shoots which grow in the axils of larger shoots (see photo). This practice will allow for plant food rising up the stem to feed the most important fruit bearing shoots.


Lower shoots should be removed (left) and the shoots growing in the axils of larger fruit bearing shoots (right)

Formation of flowers and young fruits

The formation of yellow flowers and young fruits is an important stage in the life of a tomato plant. When a large proportion of flowers produce developing fruit, it is referred to as a "good set" in gardening terms.


Increased feeding after first fruiting

Once the first few groups of flowers ("trusses") have formed and the first "sets" of very young tomatoes are starting to grow, the time has arrived to increase the level of feeding. This can be achieved by applying a pea tin full of wood ash to the soil (about 400mls or 170gms) and digging in. Also urine can be applied to provide nitrogen. Diluted urine (5:1) can be applied at the rate of around 1 litre per week or 100mls neat per week and watered in. By itself urine contains too much nitrogen in relation to potassium, so the balance must be adjusted by adding wood ash. According to Tom Manson, Zimbabwe's expert gardener, the application of wood ash to tomatoes can give "bumper crops." If too much nitrogen is given without corresponding quantities of potassium, the leaves will grow abundantly with less fruit production. When chemicals fertilisers are applied to growing tomatoes after the "trusses have set" a 3 weekly application of 5gms ammonium nitrate and 7.5gms potassium sulphate is recommended (Moran 1992). This amount of nitrogen (5g N per 3 weeks) can be supplied by

applying a 0.5 litres of 5:1 water/urine mix twice a week – or one litre per week together with regular watering. But the urine alone does not provide enough potassium – as this twice weekly application will only provide about 1 gm of potassium per 3 weeks. The potassium must be gained from other sources. This is where the wood ash is useful. It contains about 10% by weight of potassium, so in order to gain about 6 gms of potassium every 3 weeks, a heaped tablespoon of wood ash is required twice a week for each plant. To make it simple put on a pea tin of ash – one time after the first fruits have set. Experimentation is required if the eco-san gardener is to learn the best technique.




Harvesting

Tomatoes can be picked at any time after they start to turn in colour from dark green to pale green (the fruit will ripen in about one week), or when they are light red to full red. They should not be left on the plants after this stage. If everything goes well a tomato plant can yield up to 4 – 5 kg of fruits.

Disease

Tomatoes are also susceptible to fungus and other diseases, particularly during the rainy season and also to attack by eelworms, cutworm and bollworm. Care must be taken to ensure they are spaced well apart and in a position where they will be well aerated. The leaves should never be watered. Sick plants should be removed and burned. Chemicals are available to control fungal and insect problems, but in organic gardening the use of these is normally avoided.

Growing tomatoes using the “ring culture” technique

This method involves growing the tomato in a container (like a 20 litre bucket) from which the bottom has been removed. The bucket is placed over another container or layer of river sand. In this case a sealed 10 litre cement basin has been used. This significantly increases the volume of sand/soil/compost in which the tomato roots can grow and can enhance fruit production. Also nutrients added to the system are not all lost by seepage through the base of the bucket - they can accumulate in the bed of river sand. The following photos show this method put into use. The bucket is filled with a 50/50 mix of toilet compost and leaf compost. and watered until small marble sized fruits appear. At this stage extra potash is applied by adding a pea tin of wood ash to the soil. Also from this time urine is applied once a week – one litre of a 5:1 mix of water and urine. Comfrey leaves can be cut up and applied as a mulch to provide extra potassium, reduce evaporation of water and reduce the number of weeds.

The lower container is filled with river sand. The upper container is a 20 litre bucket with the base cut off. Two 10 litre buckets are filled, one with toilet compost, the other with leaf compost. These are mixed and added to the 20 litre bucket.

A young tomato seedling is added to the mixed compost and watered regularly. It is allowed to grow in the compost without additional feeding until marble sized fruits appear.


At this stage a pea tin full of wood ash is added to the soil and mixed in. Also the diluted urine can now be applied at the rate of one litre of a 5:1 mix every week. Otherwise normal watering continues. A mulch layer of comfrey leaves is also added over the soil. This reduced evaporation from the soil and also adds potassium. It also reduces the growth of weeds which would otherwise take up nutrients.

Weekly additions of the 5:1 water urine mix continue together with normal watering. More comfrey mulch can also be added. The fruits are harvested when they start to turn red

8. 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. The include banana, mulberry, guava, paw paw, avocado pear, mango and many others. 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

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 of 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). On the right the tree is growing fast in a 10 litre bucket.

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.