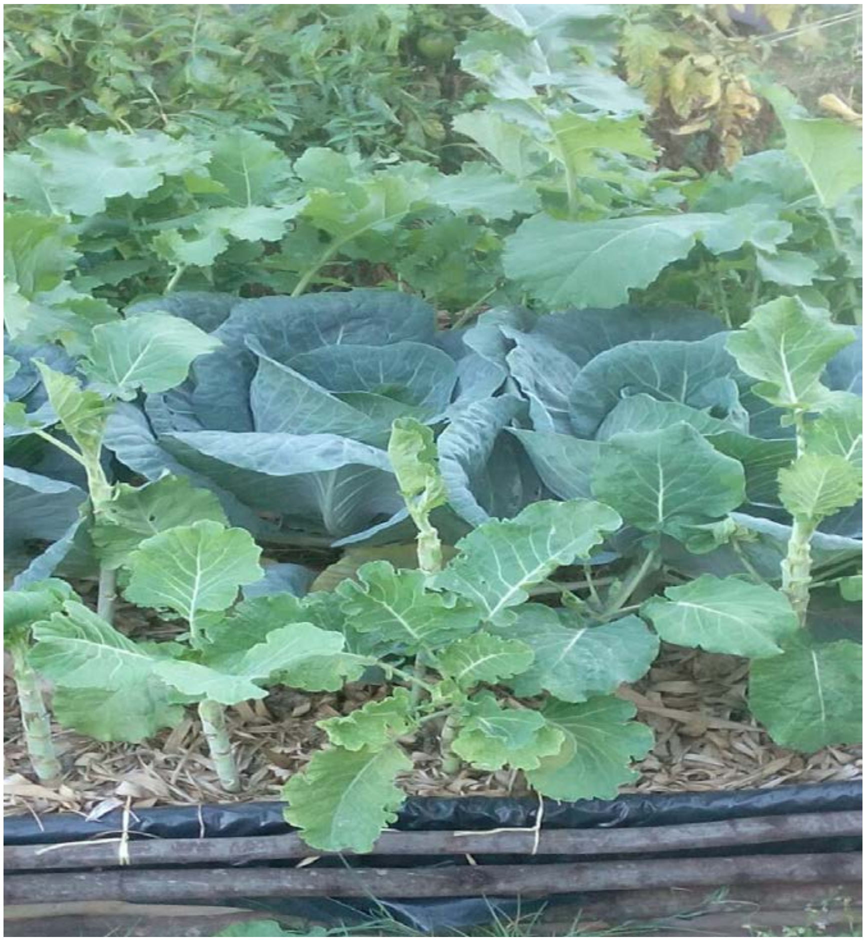
FOUNDATION FOR FARMING 100 FOLD VEGETABLE GARDENS

A. BENEFITS OF 100 FOLD GARDENS:



a. These gardens can be constructed in areas where the soils/conditions are otherwise not favorable, too rocky, water logged, concrete floors, too saline etc.
b. The growing medium is amended to be very fertile, thus able to sustain maximum growth.
c. High density planting means very small area/foot print required.
d. High density planting means greater profitability.
e. Very water conserving as no water travels beyond the root zone.
f. This system make water management simple, as known quantities are applied at known intervals.
g. Mulching prevent soil surface evaporation.
h. Mulching suppresses weed growth and allows the soil to remain soft and friable while also feeding and protecting the soil organisms.

i. Nutrients are easily managed as they to remain in the reservoir and are never leached.
j. Soluble fertilizers such as liquid manure are easily applied through the feeder pipe (thus saving time and labour).
k. The water reservoir and soil filter prevents potential fertilizer burning.
l. Raised bed allows for adequate air movement through the soil (beneficial for both plants and micro-organisms).
m. Raised bed means higher soil temperature, thus increased plant growth.
n. Subteranial irrigation means no surface watering, thus reduced weed germination, minimal soil crusting, compaction or salt build up in the soil.
o. Subteranial watering and soil scrubbing means grey water can be used, reducing water transportation.
p. Minimal labour required as almost no weeds grow and those that do are easily pulled and deposited on top of the mulch layer, to in turn feed the soil.
q. No additional digging is required at time of replanting a soil remains soft and friable.
r. Garden design creates an ideal environment for micro-organisms to proliferate.
s. Bio-bins can easily be incorporated into this system, allowing for easy composting and increased fertility (all plant juices produced travel through the soil and are captured in the reservoir for later absorption by the plants).
t. The 2x2m design with 1m walk ways between beds means there is adequate air movement around the plants minimizing disease.
u. This design also means these is good access to sunlight on all four sides and good light penetration to the center of the bed.
v. The size of the bed also means that protecting the bed is simple.
w. Simple hoops can be made to span the bed for covers against intense sun, cold and insect movement.
x. The size also means beds can be quickly constructed allowing for timely production while additional beds are constructed (earnings from the first bed can be used to pay for then next beds).

B. MATERIALS REQUIRED FOR CONSTRUCTION:

a. Builders plastic, 220 micron 3m x 100m (3m x 3m/bed)
b. PVC pipe 32^{mm} class 6 (2.6m/bed, one length cut to 2m, the other to 0.66m)
c. 32^{mm} elbows (1/bed)
d. 32^{mm} end cap (1/bed)
e. Empty grain bags (11/bed)
f. Total cost of builders plastic and PVC pipe and fitting is around $10/bed

C. TOOLS REQUIRED:

a. PICK
b. SHOVEL

c. BUILDERS LEVEL
d. SIEVE

D. DIMENTIONS OF 100 FOLD BEDS:

a. Standard size 2m x 2m x 0.3m deep. This is recommended for areas where there is water logging, (poorly drained soils) and there is abundant materials such as rocks, bricks etc. to construct a 0.2m retaining wall around the edge of the bed.
b. Alternative size: 2m x 2m x 0.4m deep. This is recommended for well drained soils, and for areas where there is a shortage of materials to construct retaining walls.

The dimensions of 2m x 2m were chosen because the plastic comes in widths of 3m and off cuts of the plastic are wasteful and increase the overall cost.

E. LABOUR REQUIERMENTS:

On a standard hole it has been found that a total of 16 man hour (at a cost of $1.00/hour) is required to complete a bed from beginning to end. Noted this all depends on the ground conditions, eg if very rocky.

F. DESCRIPTION OF CONSRUCTION:

a. Pegging of hole:
    1. Take care to measure and square the hole accurately, right angles are very important.
    2. Location considerations are important. You want the bed placed in such a way so as to give it access to the right conditions, eg full sun, partial shade etc.
    3. Location to water source is an important factor.
    4. Orientation should be considered, you want to square it to such features as existing buildings, fences etc. so as to be aesthetically pleasing. (same principle as a well watered garden, who's purpose is to be highly visible and God honoring)
    5. Consider the addition of future beds, and maximizing the space available, so as to be as efficient as possible.

b. Digging the hole:

1. Cut along the edges of the bed, so as to obtain sharp clean edges.
2. Take care to dig to the correct depth, from the lowest edge or point.
3. Make sure the bottom of the bed is level (use a builder level), so as to obtain uniform pooling of water in the reservoir.
4. Placement of excavated soil. Take care to place this where there is sufficient room to subsequently sieve this material.
5. It is very important to make sure the sides and bottom of the hole does not contain sharp objects such as rocks and roots that might puncture the liner.

c. Sieving of material:

1. As the removed soil is sieved, place the fine soil to one side for later mixing with sieved compost and manure.
2. Place the larger materials to one side as well, taking care to remove any plastic bags and other hazardous items.
3. Items such as glass, tin cans, bones are acceptable to use as backfill material and is a great way of cleaning up the environment.
4. Additional materials, if there is a shortage of good soil, it is suggested that one dig out near by drainage ditches, as these become clogged and often contain highly rich organic materials.
5. Another source is trash/rubbish piles. We have found that in the high density suburbs people dump unwanted materials along the sides of the roads hoping the council will collect. This becomes an environmental hazard , thus sieving this provides one with rich organic material and fill material, while serving the community.
6. In rural areas we suggest burn pits can be cleaned out and sieved.

d. Placement of plastic liner:

1. Insure the liner is cut to the correct dimensions. 3m x 3m for a standard 2m x 2m bed.
2. Make sure the liner is centered correctly in the hole so equal amounts of plastic stick up over each of the four edges.
3. In bare feet have one person push the plastic tightly into all the corners, and along the bottom edges of the hole. This is to prevent the plastic being stressed when being backfilled.
4. If you find the bottom of the hole still has sharp material before placing the liner, place a covering of fine sieved soil or river sand in the bottom, this will help protect the integrity of the liner.

e. Placement of the irrigation pipe:

1. Identify the corner of the bed closest to the water source.
2. Take the 2m length of 32^{mm} PVC pipe, cut slits on one side using a hacksaw about every 10cm over the entire length.
3. Cap one end with the 32^{mm} end cap.
4. Place the 32^{mm} elbow on the other end
5. Attach the 0.66m 32^{mm} PVC pipe to the other side of the elbow.

6. Fit this tightly into the corner closest to the water source, aim the 2m length diagonally across the bottom of the bed to the opposite corner.
7. Make sure the slits on the 2m length of pipe are facing downwards, so as to prevent blockage. The bags of filler will now be placed on top of this irrigation pipe.

f. Filler material for reservoir:

1. Note it is important that the fill material does not contain a high percentage of fines (see later note about surface tension).
2. Place the fill material in 11 woven grain bags. Fill the bags a little over half full, then lift then into the bed. At this point add additional material to the bag then gently lay the bag flat on top of the plastic liner, insuring the fill material is evenly distributed throughout the bag. The 11 bags placed this way cover the bottom of the bed.
3. These bags should take up the bottom 20cms of the bed.
4. One now needs to cut several horizontal slits in the plastic liner just above the 20cm level. These slits prevent the bed from flooding during rain storms.
5. If there are depression between the bags of filler, one can add additional fill on top of the bags to create a level surface.

g. Growing medium, placement and composition:

1. Determine the quality of the sieved material obtained from digging the bed. If this material is fertile, a lower percentage of manure and compost will be needed.
2. We have used a rule of thumb of 3 wheel barrows of sieved compost and 3 sieved manure to be added to good quality parent material. Obviously these ratio's will need to be adjusted for poorer quality materials. Remember the biblical principle the more you give the more you will receive. It is important to have highly fertile growing medium as we are going to have very high planting densities, for maximum yields.
3. Mix the three mediums uniformly.
4. Backfill the next 30 cms of the bed with this fine medium.

h. Edge of bed:

1. If a standard bed has been dug of 30cm deep a perimeter wall of 20 cm will need to be built to hold the plastic and contain the soil. The benefit of a slightly raised bed are many in my opinion:
   - Reduced risk of flooding during high rainfall periods
   - Allows for more air movement in the soil, both oxygen and carbon dioxide
   - Increases soil temperature, especially important during the cold season (it can be noted that the plants around the edge of the bed grow bigger while small so light competition isn't a factor at this point)
   - Clearly defines the boundaries of the bed, and prevents the bed becoming smaller over time.
   - Allows for defined areas between beds, which are easily kept clean and weed free

2. It is important the edge material hides the plastic, so as to prevent it being degraded by the UV rays
3. The growing medium should be filled right to the top of the parapet so as to ensure the full 30 cm depth.

i. Mulch layer:

1. It is essential a high quality, weed free mulch be placed on top of the growing medium for the following reasons:
    - It prevents water loss to evaporation
    - It prevents crusting of the soil surface
    - Prevents erosion
    - Protects against water impact
    - Prevents weed germination
    - Protects soil micro-organisms
    - Moderated soil temperature

J. Planting

Description of wicking bed technology by Colin Austin

How wicking beds work

A remarkable substance

To understand how wicking beds work we have to look at the characteristics of one of the most remarkable substances on the face of the earth – water.

We are so used to water we may not realize just how remarkable water is; - its' odd behavior of expanding as it freezes, its high latent heat which aids the formation of clouds but above all its intra molecular forces. These may seem abstract physical properties but the fact is we or any other living creature would not be alive to marvel at these peculiar properties if they did not exist.

The apparently simple water molecule H2O or perhaps H-O-H is polar - meaning that one end is positively charged while the other end is negatively charged. It is rather like a bar magnet with a North and South poles with each pole attracting the oppositely charged end of other molecules. The net result is that water has a tensile strength. We see this in the way that water forms into drops.

It is this tensile strength which pulls water up into the highest trees, as the water evaporated from the leaves it literally pulls water out of the soil through this extended chain.

While individual water molecules have the strongest attraction for other water molecules they are also attracted to many other materials such as soil particles and organic materials. These surface tension forces or wicking forces are seen when water rises in capillary tubes.

The finer the capillary the greater the surface tension forces are relative to gravity so water will

rise higher in a fine tube. If water molecules did not have this attraction there would be no plants and no food for us or other creatures, it is one of the basics for life.

Surface tension and the water holding capacity of soil.

Soil is made up from particles which generally have a wide range in size. The smaller the spaces between the particle the stronger they are held in the void.

Water is attracted to the surface of these particles by surface tension which tends to hold the water in place against gravity. The smaller particles and hence voids create greater surface tension forces, adequate to resist gravity. Water in the large holes does not have enough surface tension force to resist gravity and the water drains.

The wetting front

When water is applied to the soil surface it will initially fill the voids however water in the larger voids which cannot be held in place by surface tension will be pulled down by gravity so forming a wetting or flow front. When the water application stops the flow front will stabilize leaving the soil above the flow front being at field capacity.

The total amount of water held in place by surface tension is called the field capacity. Soils with very fine particles can hold more water than soils with coarse particles, a good loamy soil may hold about 15%.

This pattern is generally true for the theoretical homogeneous soils, in practice soils are rarely that uniform containing many cracks or fissures which allow water to penetrate deeper without wetting out the soil beside the cracks.

The drying front

Plants will extract the water from the soil starting with the water in the large pores near the surface. After a time this water will become more difficult to extract so the plant will now extract water from deeper in the soil.

This gives what is in effect a drying front. After a time the plant can no longer extract adequate water from the soil. There is still water in the soil but it is tightly locked into the smaller pores. This is called the wilt point and the amount of water between field and wilt is called the available water.

Soils with fine particles may hold more water but this water is more difficult to extract. Soils with course particles will hold less water but it is easier for the plant to extract. The field and wilt point will vary widely between different soils but the water available to the plant is generally only about 10% of the total volume of the soil.

Water holding capacity of a wicking bed

The total void content of the soil may be 30% of the total volume so if the soil is totally saturated with water then the volume of water held in the soil will be about 30% of the total volume or some double the field capacity.

The essential feature of the wicking bed system is an underground reservoir of water in immediate contact with the soil in the root zone. This water reservoir is typically filled with a coarse organic material which has a large void content and will offer less resistance to water being pulled out by surface tension from layers above. This increase the readily available water several fold, and is an important feature of the wicking bed system.

Deep and shallow irrigation

Short irrigations are very inefficient.

The water in the top surface layer (50mm) will quickly evaporate and be lost leaving the soil dry.

At the next water application this dry soil will have to be wetted before any water enters the root zone.

Typically the first 10mm of water applied will be lost. This means that short frequent irrigations are very inefficient with significant loss of water.

Deeper irrigation so the flow front just reaches the base of the roots is the most efficient. However it is very difficult to know how much water to apply so the flow front just reaches the base of the roots.

Over irrigation so the water passes beyond the root zone waste water and can also cause environmental pollution.

Water below the root zone

The soil in the root zone will become drier as the plants extract water. The small pores will create a tension trying to pull water up from below the root zone.

However this tension will be resisted by surface tension and gravity. There may be sufficient pull to raise the water a small amount possibly 20mm but in reality there is very little upward movement. Essentially any water passing beyond the root zone is effectively lost to the plant.

This water may contain nutrients which will eventually enter the water tables and possibly river systems or water supplies.

The irrigator's dilemma

If the irrigator applies frequent but shallow irrigations much of the water will be lost by evaporation. Applying deeper but less frequent irrigations is more efficient but can easily lead to loss of water past the root zone, valuable nutrients and can cause environmental pollution.

The wicking bed is a solution to this problem. In its simplest form a water reservoir catches any excess water from above ground irrigation and feeds it back to the plants as they use the water. In more advanced versions water is fed directly to this reservoir so all the plants water needs are supplied from the reservoir by wicking action.

The essential feature of the wicking bed system is the water reservoir filled with a coarse aggregate which is saturated with a significant volume of water which is not held tightly by surface tension. This water is free to wick up to the layer of soil containing the root zone.

This contrasts with the traditional system in which a much smaller volume of water is held in the soil below the root zone. The restraining surface tension forces in this soil mean there is very limited ability to wet the soil in the root zone above.

Closed wicking beds

Soil in a closed wicking bed is totally isolated from the parent soil. They are more suited for shallow rooted plants such as vegetables.

The plastic sheet is now much wider extending the full width of the bed.

The simplest way of making a closed bed is to scoop out the top 200 or 300mm of soil, line the trench with plastics, place the distribution pipes, back fill with open organic mix and then replace the top soil to form a semi raised bed.

Water capture

In many areas there is insufficient irrigation water. The wicking bed system can be modified to capture and amplify rainfall by simply adding wings or extension to the wicking bed to capture water.

If for example the area of the wings it equal to the area of the bed you may think that this has effectively doubled the rainfall.

The amplification is much greater than this as small rains landing on soil only wet the surface and the water will quickly evaporate. The wings are made from an impervious material such as plastic sheet covered with stones. The water is not absorbed but instead flows down to the base of the water reservoir where it is protected. This makes use of small rains and dew otherwise wasted and is an important part of water harvesting.

Depth of wicking beds

The depth of the reservoir should not be greater than the height which water will wick upwards, generally this is 300mm. If the reservoir is deeper than the wicking height there will be a stagnant pool of water remaining which cannot feed the root zone. This will impair scheduling based on reservoir depth.

Reservoir depths of 200m work well and are commonly used. In a closed wicking bed the depth of the soil above the reservoir should be adequate to accommodate the root system of the plant. Again the normal range is 200mm to 300mm.

In an open wicking bed there must be enough soil for the water to wick upwards and sideways to the plants. A depth of 100mm will allow adequate wicking while avoiding surface evaporation.

Increased productivity

The early wicking beds were made by simply under laying a conventional furrow with a plastics liner. The initial aim was to simply stop water passing beyond the root zone and increase the water holding capacity.

An increase in productivity, far greater than expected from better irrigation, was immediately noted. The question was why? The explanation appears to lie in the differences in the way conventional and wicking beds actually work. In conventional irrigation the soil is initially very wet, above field capacity and near saturation. It is a reality that water movement through the soil is very limited until the soil is above field capacity.

This means that for a period at least, the plants roots are sitting in very wet soil which reduces growth.

In the wicking bed system the water is wicking upwards from a saturated bed below the roots and the moisture content gradually reduces to be almost dry at the surface. In other words the soil in the root zone is moist - not wet so there is adequate oxygen in the roots so the roots can breathe.

Scheduling with closed wicking beds

Closed beds

Closed beds are very easy to schedule.

Irrigation is needed when the water reservoir is empty. Irrigation water may be applied by any conventional means e.g. sprinkler, drip or furrow but preferably directly to the water reservoir by a distribution tube. The inspection pipe indicates when the reservoir is full so irrigation should be stopped. (A moisture sensor can be used for automatic operation).

It is not critical when to irrigate. Even if the reservoir is empty there will still be water in the soil above, so the plants will not suffer if irrigation is a little late. If there is a little water left in the reservoir it is not important as it will simply take less water to fill. However it is good to let the water completely dry up from time to time as this stops the water becoming stagnant.

Wicking bed with biological decomposition

It was mentioned that the one of the benefits of the wicking bed system is that the soil is maintained moist and is not saturated as in conventional irrigation.

These conditions are good for plants but are also good for microbial action. Soil structure is very dependent on this microbiological action, particularly the fungi which have long hyphae which exude a sticky glue like material which provide structure to the soil and keeps the soil particles apart and provide voids for roots, water and nutrients.

Some fungi, the mycorrhizal fungi, form beneficial relationship with the roots, with their fine hyphae increasing the surface are in contact with the soil by up to one thousand times.

Here different types of fungi are being tested in lab scale wicking beds.

In a wicking bed production system there is continual removal of nutrients which must be replaced. There is (or should be) very little flushing with a wicking bed so replacing the nutrients with chemical fertilizers could easily lead to over application and destruction of the sol structure.

To date the preferred method is to have a bio-box on the wicking bed where bacteria, fungi and worms can breed up and re-fertilize the soil. This can be topped up with organic waste and such fertilizers as are really needed. Inoculators of the appropriate bacteria and fungi help to decompose the waste into useful nutrients for the plant.

Water is sprayed into the bio-box which will flush the nutrients into the distribution pipe and hence to the plant roots.