Technical Note # 95

100-Fold Vegetable Gardens with Low-Cost Wicking Beds

What's Inside:

By Lance Edwards, with ECHO Staff

Photos courtesy of Lance Edwards

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INTRODUCTION

What is a 100-fold garden?

I discovered 100-fold gardens while researching ways to irrigate plants directly in the root zone. I wanted to know how to practically and affordably control some of the variables that influence plant growth, such as water availability and soil fertility. I read about "wicking beds," which are watered from below as water moves up towards plants' rooting zone from a reservoir lined with plastic. Watering from below prevents water loss while maintaining constant soil moisture and supplying water and nutrients in accordance with plant needs.

The wicking beds that I read about were primarily built above ground and used expensive containers and other materials. Proponents recommended potting soil to fill the beds. I began experimenting with local materials to reduce the cost of the beds. I did not want to have to purchase expensive containers or soil, so I decided to dig the beds 30 cm into the ground. That way, the ground would serve as the container, and we could sieve the soil from the hole and use it as the growing medium; it ends up being a fine growing medium that remains friable and that wicks water and nutrients well. We used the rocks and other large objects that were left in the sieve as part of the filler for the bottom of the beds. We were also able to dispose of old tin cans, bottles, broken glass, bones, etc. in the bottom part of the beds.

Wicking beds are a way of maximizing vegetable production on raised beds, but many people do not have a prior understanding of wicking in the context of gardening—so I call my version 100-fold gardens. That name comes from a Biblical reference (to Jesus' parable of the sower, in which seed sown on good soil grew into plants that yielded 30, 60 or 100 times what was sown). I wanted to be able to communicate Biblical principles with the gardens—faithfulness; giving to receive; being a gracious giver—and all of those things were incorporated in the name. I also like the name because these beds are incredibly productive if you take the time to build them properly and add the right inputs.

I have put about 150 of these 100-fold gardens into rural communities, and people have loved them. I've found them to be especially well-received and looked after by people who struggle to get water: the elderly, single moms, etc. They quickly see the value of the gardens and really take good care of them. One nice thing is that we can put the gardens right next to their home and they can use their grey water in them. By contrast, most of the gardens tend to be away from the homes, down in the riverbeds in rural areas, and it makes it much more difficult for people to secure them and take care of them.

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We add worm bins in the beds so that we can compost organic materials produced in the bed. The bins are easy to incorporate. I use a 5-L plastic ice cream container. I put a piece of ½" or 3/4" steel pipe in the fire and make it really hot, then use it to burn holes in the sides and bottom of the container. The heated pipe sears the edges of the hole and doesn't leave any sharp edges. Then I dig the bucket into the soil so that the top edge sits level with the surface of the soil in the bed. I seed the bed with a few worms to get the whole process started, and I throw a little bit of compost in the bottom of the bin and then add organic waste, which composts in the bin. Organic material from the bed, leaves that are pruned or trimmed, and weeds that are pulled are either added to the mulch on the bed or thrown into the composting bin. The bin quickly becomes very rich in organic matter and nutrients, and the worms can move from the bin to the bed and back again. When I am watering, about once a week I water the compost bin, flushing the nutrients from the worms' castings down into the water reservoir, where they can be taken up and used by the plants. This means that we are able to recycle all plant material in the beds except the vegetables that are eaten.

Where do they work best?

Wicking beds are extremely efficient in their use of water, making them an excellent option for dry areas or dry times of the year. Wicking beds do not have to be watered as often as conventional garden beds, so they are also a good option for situations in which daily watering is not possible. Wicking beds are less suited to areas with high rainfall; flooding is a problem without adequate drainage, and large influxes of water make it more difficult to feed nutrients to the plants.

There are many types of wicking beds, with a range of materials used. Our approach utilizes inexpensive materials available in Zimbabwe. Similar materials are likely to be available in other countries. The 100-fold garden is ideal for growing high-value vegetables in small plots.

BENEFITS OF 100-FOLD GARDENS

The benefits of 100-fold gardens are many!

Versatility. 100-fold gardens can be constructed in areas where the soils/conditions are otherwise not favorable (e.g., the land is too rocky, the soil is waterlogged or too saline, the area has concrete floors, etc.). High density planting means a very small area/foot print is required; it can also mean greater profitability.

Water conservation. 100-fold garden beds conserve water, because no water travels beyond the root zone. Water management is simple, with known quantities applied at known intervals. Mulching prevents soil surface evaporation. Because water is added below the plants, and is filtered through soil before reaching plant roots, grey water can be used for irrigation.

Nutrient management. The growing medium is amended to be very fertile, thus able to sustain maximum growth. Nutrients can be easily managed, because they remain in the reservoir and are never leached into the ground. Mulch keeps the soil soft and friable. The water reservoir and soil filter reduce the likelihood of fertilizer burning the plants (for example, through salt buildup). That said, I have never found any issues with fertilizer burn.

The garden design creates an ideal environment for microorganisms to proliferate. The raised beds allow for adequate air movement through the soil, which benefits both plants and microorganisms. Additionally, the mulch and water reservoir feed and protect microorganisms from wide fluctuations in soil temperature and moisture.

Small boxes called bio-bins can be easily incorporated into this system, allowing for composting and increased fertility (all plant juices that are produced travel through the soil and are captured in the reservoir for later absorption by the plants).

Minimal labor. After the initial labor of setting up the garden beds, little labor is needed. 100-fold garden beds require very little weeding, because the heavy layer of mulch means almost no weeds grow. Those that do grow can easily be pulled and deposited on top of the mulch layer, to feed the soil in turn. When replanting, the soil remains soft and friable, so that no additional digging is required. Soluble fertilizers such as liquid manure are easily applied through the feeder pipe (thus saving time and labor). Subterranean irrigation means no surface watering, which results in fewer weeds germinating. It also means minimal soil crusting, compaction, or salt build up in the soil.

Less disease. The 2 m X 2 m design with 1 m walkways between beds means there is adequate air circulation around the plants, minimizing disease.

Sunlight. The design also means that plants have good access to sunlight on all four sides and good light penetration to the center of the bed.

Convenient design. The size of each garden bed means it is easy to protect. For example, simple hoops can be made to span the bed to protect against intense sun, cold and insect movement.

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 the next beds).

CONSTRUCTING A 100-FOLD GARDEN BED

Materials Required for Construction

- Builders plastic, 220 micron (thickness) 3 m x 100 m (3 m x 3 m per bed)
- PVC pipe 32 mm class 6 (2.7 m per bed, one length cut to 2 m, the other to 0.66 m); alternatively, a 5-L plastic bottle (see construction step 5)
- 32 mm elbows (1 per bed)
- 32 mm end cap (1 per bed)
- Empty grain bags (11 per bed here in Zimbabwe; the number needed depends on the size of the bags)

In Zimbabwe, the total cost (of builders plastic, PVC pipe and fittings) is around $10 per bed.

Tools Required

- Pick
- Shovel
- Builders' level
- Sieve

Dimensions of 100-Fold Beds

The standard bed size is 2 m x 2 m and is dug 30 cm deep (Figure 1). This is recommended for areas with waterlogged soils (due to poor drainage) and where there are abundant rocks, bricks, etc. to construct a 20 cm retaining wall around the edge of the bed.

Alternatively, the bed can be dug 40 cm deep. This is recommended for well- drained soils, and for areas with few materials to construct retaining walls.

We chose width and length dimensions of 2 m because the plastic comes in widths of 3 m. Off-cuts of the plastic are wasteful and increase the overall cost.

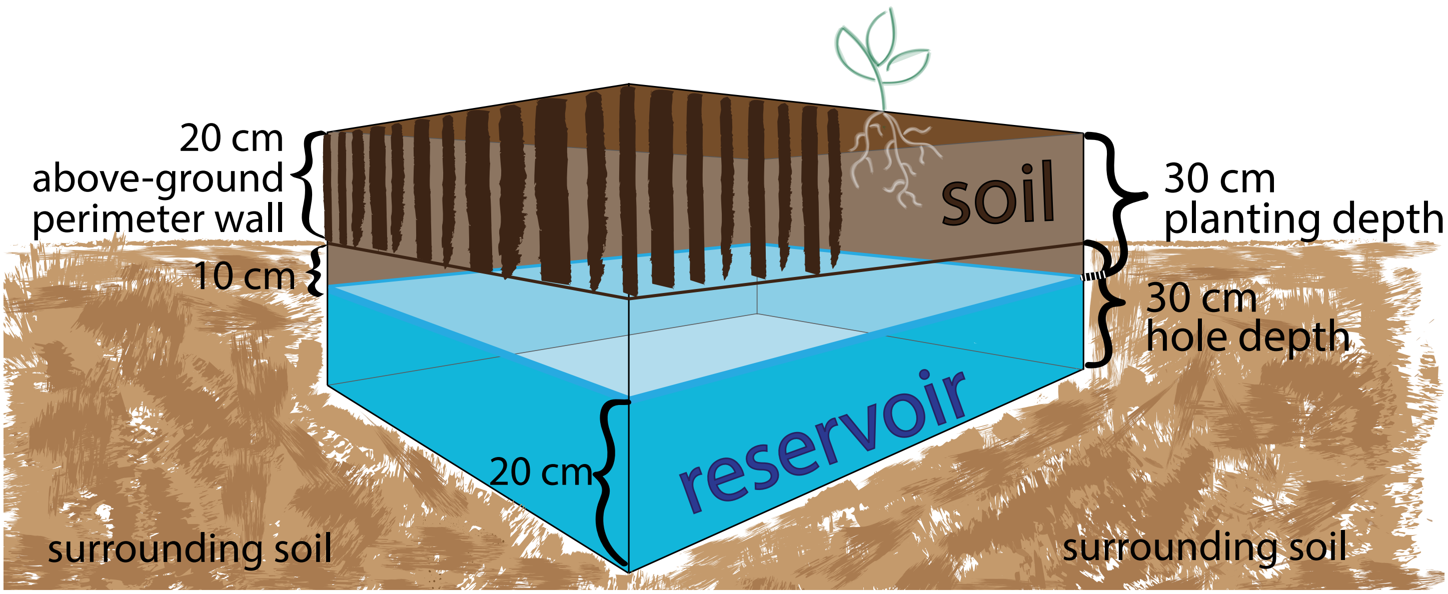

Figure 1. Dimensions of key elements of a 100-fold garden. *Diagram by Stacy Swartz*

Labor Requirements

On a standard hole, we found that 16 man-hours (at a cost of $1.00/hour) are required to complete a bed from beginning to end. However, this depends on the ground conditions; if the area is very rocky, the hole will take longer to dig.

Construction Steps

1. **Place the hole (Figure 2):**

   Consider location. Place the bed in a way that will give it access to the right conditions (e.g. full sun, partial shade etc.). Also think about the bed's location in relation to your water source.

   Consider orientation. Align the bed with edges of existing buildings, fences, etc., so that the result will be aesthetically pleasing. (This is the same FFF principle as is used for a well-watered garden, which is meant to be highly visible and God honoring.)

   Maximize space. Consider the possible addition of future beds, and maximize available space.

   Measure carefully. Be sure to measure and square the hole accurately. Right angles are very important.

Figure 2. Hole excavated for a 100-fold garden.

2. **Dig the hole:**

   Cut along the edges of the bed, to obtain sharp clean edges.

   Dig to the correct depth, from the lowest edge or point. Make sure the bottom of the bed is level (use a builder level), so that water will pool uniformly in the reservoir.

   Remove any sharp objects (such as rocks and roots) from the sides and bottom of the hole, to keep them from puncturing the liner.

   Place excavated soil where there is sufficient room to subsequently sieve this material.

3. **Sieve the material that will be used in garden beds (Figure 3):**

   Sieve the soil as it is removed from the hole. Place the fine soil to one side, to later be mixed with sieved compost and manure. Place the larger materials in another spot, taking care to remove any plastic bags and other unwanted and/or hazardous items.

   Collect additional materials. If you lack good soil, consider digging out nearby drainage ditches, which can become clogged and often contain highly rich organic materials. Items such as glass, tin cans, and bones are acceptable to use as backfill material. This is a great way of cleaning up the environment.

   Also check trash and rubbish piles. We find 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. Sieving these piles can provide rich organic material and fill material, while serving the community. In rural areas, burn pits can be cleaned out and sieved.

Figure 3. Sieving of soil for later use in a 100-fold garden.

4. Place the plastic liner (Figure 4):

Before placing the liner, if you find that the bottom of the hole still has sharp material, cover it with fine sieved soil or river sand to help protect the integrity of the liner.

Cut the liner to the correct dimensions. For a standard 2 m x 2 m bed, cut the liner to 3 m x 3 m.

Make sure the liner is centered correctly in the hole, so equal amounts of plastic stick up over each of the four edges. Then have one person in bare feet push the plastic tightly into all the corners, and also along the bottom edges of the hole. This is to prevent the plastic being stressed when being backfilled.

Figure 4. Plastic liner placed along the bottom and sides of a 100-fold garden.

5. Place the irrigation pipe:

Identify the corner of the bed closest to the water source. This is where to place the vertical part of the water pipe (Figure 4).

Using a hacksaw, cut slits on one side of the pipe about every 10 cm over the entire length. Cap one end of the 2 m length with the 32 mm end cap. On the other end, attach the 32 mm elbow (with the slits on the 2 m length of pipe facing downwards). Create the vertical portion of the pipe by attaching the 66 cm length of 32 mm PVC pipe to the other side of the elbow.

Fit the vertical portion of the 2 m pipe tightly into the corner closest to the water source identified earlier. Aim the pipe diagonally along the bottom of the lining (Figure 4) to the opposite corner. As alluded to above, ensure that the slits of the pipe face downwards to prevent blockage. Bags of filler will be placed on top of this irrigation pipe.

As I have worked with people on these gardens, I have found that few people have access to PVC pipe, especially in a rural setting, so I came up with an alternative irrigation method. Often I suggest that they use a 5 L plastic bottle (such as an empty cooking oil bottle or something similar). They cut the bottom off the bottle, then invert that with the lid off. The inverted bottle becomes the funnel where they can pour in the water. It is quite a big funnel, but that makes it easy to pour the water in. Lately I also tend not to run a pipe across the bottom of the bed; instead, I allow the water to self-level. In a small 2 m x 2 m bed, the water easily travels across the bed and self-levels.

6. Add filler material for reservoir:

Place fill material into woven grain bags (Figure 5). The number of bags needed will depend on their size. In Zimbabwe and elsewhere, 50 kg grain bags are commonly available; 11 of these fills a 2 m X 2 m reservoir. However, the size of the bags is not important, nor is the number. Just be sure to fill enough bags, and orient them to cover the floor.

Fill material can be anything. What medium you use for fill will depend on what is inexpensive and locally available. Small rocks, gravel or coarse river sand are commonly used. The fill ought to consist mostly of coarse-textured material, providing plenty of pore space (see later section on underlying concepts). In addition to small rocks/gravel, soil, and organic matter, the fill material can include rubbish such as bottles, broken glass, bones and tin cans (see step 3). Inorganic, non-degradable materials bear the weight of the soil that will be placed on top, while organic matter and soil facilitate wicking and accommodate roots growing into the reservoir.

Figure 5. Bags of fill being added to the reservoir of a 100-fold garden.

Fill the bags a little over half full before lifting them into the bed. Then, one at a time, fill the rest of each bag with additional material. I try to make sure that the fill I put in the bottom bags is quite well-compacted, to avoid any future settling of the bed and of the soil above it. Once the bags are filled, gently lay each bag flat on top of the plastic liner, ensuring that the fill material is evenly distributed and 20 cm thick (so that the height of the bags is 20 cm from the bottom of the bed). Be very careful not to perforate or puncture the liner; we don't want to compromise the waterproof integrity of the liner. Arrange the bags as needed to cover the bottom of the bed. If there are depressions between the bags of fill, you can add additional fill on top of the bags to create a level surface. Typically, once I have placed bags in the bottom of the bed, I try to fill any cracks and gaps with a finer medium such as river sand.

After the fill bags have been placed, cut several horizontal slits in the plastic liner just above the 20 cm level. These slits will prevent the bed from flooding during rainstorms.

7. Add growing medium, considering placement and composition:

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.

We generally add three wheelbarrows of sieved compost and three wheelbarrows of sieved manure to good quality parent material. More compost and manure will be needed if the soil is of poorer quality. Remember the biblical principle that the more you give, the more you will receive. It is important to have highly fertile growing medium, because we are going to have very high planting densities, for maximum yields.

Mix the three mediums uniformly. Backfill the next 30 cm of the bed with this fine medium.

8. Finish the edge of bed (Figure 6):

If a standard bed has been dug 30 cm deep, build a perimeter wall of 20 cm to hold the plastic and contain the soil. The benefits of a slightly raised bed are many in my opinion:

- Reduces 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
- Clearly defines the boundaries of the bed, and prevents the bed from becoming smaller over time.
- Allows for defined areas between beds, which are easily kept clean and weed free

Figure 6. Rocks used to form the edge of a 100-fold garden.

Make sure the edge material hides the plastic, so that the sun's UV rays will not degrade it.

Add growing medium right to the top of the edge wall, to ensure the full 30 cm planting depth.

9. Add mulch layer:

Figure 7. Mulch on the top of a 100-fold garden.

Place a high quality, weed-free mulch on top of the growing medium (Figure 7). This is essential for many reasons. It prevents water loss due to evaporation and prevents crusting of the soil surface. Mulch protects against water impact when it rains, reducing erosion. The layer of material blocks the sun, preventing weeds from germinating and moderating soil temperature. Mulch also protects soil microorganisms from exposure to the harsh sun.

10. Plant

Plant the wicking bed using seeds or transplants. Plant deep enough for contact (of seed or roots of transplants) with moist soil. Mel Bartholomew's square-foot gardening planting chart works well for spacing plants in the 100-fold garden; typically this means we plant at quite a high density. Consider what you will be harvesting and the size of the harvested product (e.g., a radish versus a head of cabbage), and space your plants accordingly. If you use stakes or trellises to support tall or vining plants, do not push them all the way to the bottom of the wicking bed; this could puncture the liner.

In line with Mel Bartholomew's recommendations, I tend to suggest that people grow leafy greens in 100-fold garden beds. We plant these crops densely, but as the plants grow, people pick the leaves and naturally thin them. I do not suggest that people plant things like cabbages in these gardens, because they grow so big--the number of cabbages you could plant in one of these beds is low compared to something like collards.

I also do not promote tomatoes for these beds, because tomato plants get very big and take up a lot of room. Instead, I suggest that people plant tomatoes in a similar way, but that they use the principles of the 100-fold garden in 20 L buckets and plant a tomato plant in each bucket. It works well, and the nice thing about one of these is that a person can place it anywhere in their yard or garden where it can get adequate sunlight, and they can place it far away from other crops for disease prevention.

HOW WICKING BEDS WORK

Summary by Tim Motis of content by Colin Austin (2015) and others. Austin is a pioneer of wicking beds.

Underlying concepts:

In this section we introduce underlying concepts, to build understanding of how wicking beds maintain adequate soil moisture in the planted layer. Texts such as *The Nature and Properties of Soils* (Weil and Brady 2016) cover these concepts in depth.

Soil texture determines how much water a soil can hold

Fine-textured silt or clay soils have smaller particles than sandy soils. The larger the particles, the larger the pores (spaces between particles) they have. Pore spaces can be filled with air and water. The large pores in sandy soil enable water to infiltrate and drain more quickly than in clay soils. Clay soils, however, hold more water than sandy soils because they have more pores than sand.

Molecular characteristics of water affect its retention and movement in soil

A water molecule is polar, having a positively charged oxygen atom on one end and two negatively charged hydrogen atoms on the other end. The positive end of a water molecule is attracted to the negative end of another water molecule, or to negatively charged surfaces of soil or organic matter particles. These attractive forces are the basis for **soil water tension** and **capillary action**. The smaller the soil particles, and the pore spaces between them, the stronger the tension by which water in the soil is held against the downward force of gravity.

Moreover, the smaller the soil pores, the greater the capillary action or force by which water is "squeezed" through them. Capillary action explains the ability of water to move upwards in a wicking bed. As the soil around plant roots dries (due to root uptake and evaporation through the leaves), water wicks from the surrounding soil and, ultimately, from the water in the reservoir.

Not all of the water in a soil is available to plants

When rainfall or irrigation saturates a soil, the pore spaces fill with water. Some of that water is lost to plants as it drains downwards, past the root zone. A soil is said to be at field capacity after drainage of a saturated soil stops. The drier the soil becomes, the more tightly the remaining water is held to soil particles, making it increasingly difficult for plant roots to extract it. When plants can no longer extract water, a soil is said to have reached the permanent wilting point. At the wilting point, some water is still present in the soil, but it is inaccessible to plants. Total available water, then, is the soil water content at field capacity minus the soil water content at the wilting point.

Application of underlying concepts to the following key elements of a wicking bed

Constant contact between the soil and water

In a wicking bed, the soil in which plants are grown is in direct contact with water in the water reservoir. Most of the fill material in the reservoir is coarser than soil in the planted layer above. Water is not held as strongly to reservoir fill as it is to soil in the planted layer above. Thus, water freely wicks upwards—via the combined forces of soil water tension and capillary action—towards plant roots. Plants receive just the amount of water they need, since the rate at which water wicks upward is faster or slower depending on how quickly plants are extracting water from the soil.

At the same time, pores in the soil and in the organic matter component of reservoir fill (see construction step 6) are small enough to facilitate capillary rise, enabling water to wick up to a greater height than if all of the fill were comprised of gravel or sand. Any downward extension of roots into the reservoir further strengthens the connection between water in the reservoir and the soil above. Thus, moisture in the upper layer (where plants are grown) is maintained even when water in the reservoir is nearly empty.

Depths of the growing media and water reservoir

Semananda *et al.* (2016) compared soil moisture in wicking beds with 60 cm versus 30 cm of growing soil. They found that the top 0 to 10 cm of the planted layer was drier, and tomato yields were lower, with 60 cm than with 30 cm of growing soil. They mention that the deeper the planting soil is, the more difficult it is to supply enough water with capillary action. Their finding is consistent with the 30 cm soil depth used in Zimbabwe. A growing depth of 30 cm accommodates the root systems of most annual vegetables and falls within the 25 to 40 cm range recommended by Palmer and Grubb (2016). The top few cm of soil and mulch should be dry, reducing weed growth while preventing loss of water to evaporation.

Semananda *et al.* (2016) also compared wicking beds with water reservoir depths of 15 and 30 cm. Tomato yields were not affected by these depths, suggesting that depth of the growing area is more critical than that of the reservoir. However, we do not advise going much shallower or deeper than 20 cm. With shallower depths, water has to be replenished more often. With deeper depths, reservoirs become more laborious to dig. Austin (2015) suggests a range of 20 to 30 cm.

Water delivery and efficiency

Water can added to the surface using methods such as watering cans and drip irrigation. For maximum efficiency, however, add water directly to the reservoir, through the top of the irrigation pipe. Pour water from a watering can or bucket into a funnel attached to the pipe. Alternatively, pump water through a hose inserted into the pipe.

Watering from below simplifies irrigation scheduling, requiring less frequent watering. When the reservoir is empty or nearly empty, add water (through the irrigation pipe) to bring the water depth back to 20 cm. Waiting until the reservoir water is used up keeps the reservoir from becoming stagnant and developing an unpleasant odor. It also keeps minerals from building up in the reservoir, which could have the same adverse effect on plants as a saline soil. Depending on the rate of plant water uptake, it can be days or even weeks before the reservoir needs refilling. Use the irrigation pipe as an inspection pipe to gauge the level of water in the reservoir. If you cannot see the water level, insert a dry stick into the pipe, take it back out, and check the height of the stick wetted by the water.

Supplying water from below not only reduces watering frequency but also the amount of water needed, which is important for dry areas. Table 1 below describes water losses that can occur with overhead forms of irrigation, and how wicking beds minimize those losses. In comparison to surface application of water, Semananda *et al.* (2016) observed up to 22% water

Table 1: How wicking beds prevent water loss that occurs when supplying water to the soil surface.

Sources of water loss with surface irrigation*		Mechanism by which wicking beds prevent water loss
Runoff		The reservoir keeps water in the wicking bed. Some rainfall or surface-applied irrigation water could run off the top of the bed. Mulch helps with this, as well as watering from below by adding water through the irrigation pipe.
Leaching		The plastic liner blocks drainage past the bottom of the reservoir.
Evaporation		As long as the growing layer is not too shallow, the surface remains dry, minimizing evaporation.

*The extent of water loss varies with irrigation method. For example, losses are much less with drip irrigation than with watering cans or overhead sprinklers.

savings by watering from below. They mention that, in practice, water savings could be greater because most gardeners do not apply water as precisely as in a research trial. Austin (2015) mentions that wicking beds have been shown to reduce water use by 50% in comparison to surface watering.

Adding nutrients to wicking beds

Wicking beds are fertilized with minimal effort by adding fertilizer or manure tea through the irrigation pipe. Lance Edwards commented, "[In Zimbabwe], I do not promote any commercial fertilizer in these beds. I promote use of composting and cow manure, and also of human urine, which is what I really promote as the fertilizer of choice. I encourage people to mix it at a 1:5 ratio of urine to water, and then pour that into the pipe or funnel. The mixture goes to the bottom of the bed and doesn't come into contact with any edible part of the plants, so there is no chance of infection or disease on the leaves."

Another method of fertilizing is to incorporate a bio-bin into the surface layer (Figure 8). Place organic waste into the bin to produce compost and/or feed earthworms. Over time, the nutrients generated will be circulated throughout the wicking bed.

Figure 8. Worms and kitchen waste in a bio-bin (left) with a hole in the side of the container (middle) for release of nutrients to the garden bed. The bin is buried so that the top of the container is level with the soil surface (right).

The plastic liner prevents loss of nutrients to leaching. As water wicks up from the reservoir, it carries dissolved minerals. Feeding plants through the reservoir is an efficient means of meeting plants' fertility requirements.

Because salts readily accumulate in the reservoir, and no leaching occurs, wicking beds generally need less fertilizer than conventional gardens. Allow time for the reservoir to empty before refilling it, to reduce any risk of fertilizer burn.

VARIATIONS OF WICKING BEDS

Austin (2015) distinguishes between closed and open wicking beds. This technical note focuses on closed wicking beds, which are completely separated from the surrounding soil.

Open wicking beds, on the other hand, are connected to the adjacent soil. They consist simply of an irrigation pipe on top of a plastic liner placed in a furrow (Figure 9). The depth of the furrow is such that the liner rests below the root zone of the plants. As in a closed wicking bed, water added from below (through the pipe) or above (applied to the surface) wicks up to feed the plant. Unlike closed wicking beds, however, the plants are placed outside the liner, beside the furrow. Open wicking beds work well for larger areas and for plants with roots that would be too deep for a closed bed to accommodate.

Aboveground wicking boxes are also used. They are made from any kind of material (e.g., old tanks, tubs, wood, shade cloth, or bricks) that can be formed into a box to hold the water and media in place. Create the reservoir by placing a plastic sheet on the bottom. Install a vertical feeder/irrigation pipe in the middle, with the bottom of the pipe above the plastic. The depth of the reservoir is determined by the height of the sides of the plastic or that of a drainage hole or pipe. Fill the reservoir with coarse material such

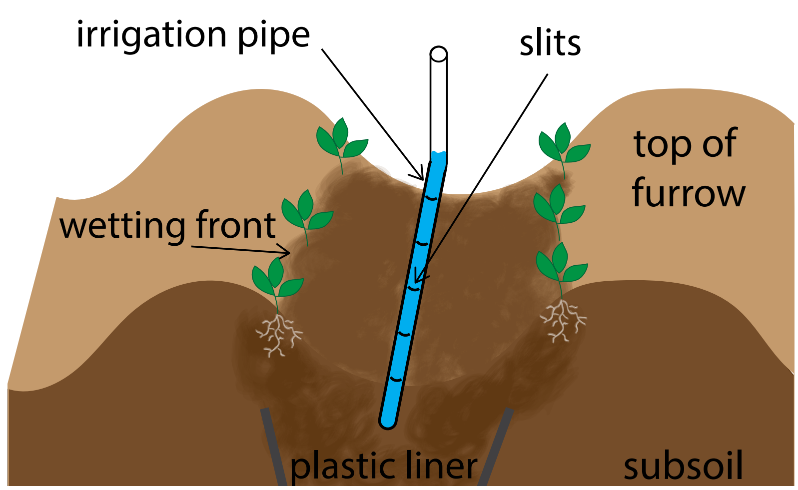

Figure 9. Diagram of open wicking bed. *Diagram by Stacy Swartz (adapted from Austin 2015)*

as sawdust or sand, with planting media placed on top of the reservoir fill. Palmer and Grubb (2016) suggest including columns of soil in the reservoir to create a capillary connection between the reservoir and the growing area. Figure 10 shows an above-ground version of a 100-fold garden at ECHO in Florida.

Figure 10. Construction of an above-ground wicking bed at ECHO in Florida. *Source: ECHO staff*

CONCLUSION

The 100-fold garden, based on the concept of wicking beds, is a highly efficient way of supplying water and nutrients to vegetables on raised beds. Excellent growth is due in large part to their ability to keep the soil from drying out and to supply moisture as plants need it. Other growth-promoting benefits include reduced weed growth, good air circulation for minimizing plant diseases, and access to sunlight.

Making 100-fold gardens includes an initial modest cost for materials and labor. However, once established, the beds require little effort to maintain. Gardeners can easily determine when it is time to add water to the reservoir, and they need to water the gardens less frequently than they would with conventional beds that rely on surface irrigation.

Wicking beds can be made and optimized in various ways. Their small size makes them easy to cover, to protect plants against insects or adverse weather. Sidewalls can be made with rocks or wood, depending on what is available (Figure 11). Variations of wicking beds besides the 100-fold garden, such as open wicking beds, could bring many of the same benefits to larger-scale plantings and deep-rooted plants.

Figure 11. 100-fold gardens with edges from stones (left) or wood (right).

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