ECHO

Technical Note #31

Rooftop and Urban Gardening

What's Inside:

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Tire gardens at ECHO. Photo by Tim Motis.

What can a family do if the national unemployment rate is over 50%, wages are a dollar or two a day, prices of food are increasing and may at times be even higher than in the USA, they have neither savings nor credit and there is no governmental safety net?

For many, an option of last resort is to find a piece of land somewhere and try to grow enough to at least keep the family alive. But how does someone in an urban area with nonexistent financial resources get land to cultivate? Often, the best option is to go beyond the frontier of where commercial agriculture has gone–essentially to some place that people with money do not want.

Such land has many disadvantages. It is typically remote from markets, which means prices for produce are very low and agricultural inputs expensive. Often there is environmental damage when steep hillsides are cultivated or forests are cleared to make way for crops. Yields are low and uncertain due to infertile soils and unreliable rainfall. Farming in these situations is difficult!

But there is another frontier for agriculture that has been overlooked almost everywhere, and that is the frontier above us! *In contrast to the difficulties and environmental harm common to the last frontiers for in-ground agriculture, farming on urban rooftops has many advantages.*

- *The urban gardener can sell at full retail price because there is no need for transportation and middlemen.*
- *The environment inside the house and even in the community is improved as the gardens absorb energy from the sun, thus lowering the temperature of the air and of the roof of the building.*
- *Production is more consistent because it does not depend on unpredictable rainfall (assuming that city water is available).*
- *Finally, no fences are needed to protect the garden from wandering livestock.*

Where might sites for these above-ground gardens be found? For starters, in many cities there are countless hectares of flat cement rooftops and many more hectares of tin roofs on insubstantial shanties. There are also steep hillsides, extremely poor soils, yards of rock or cement, spaces around tree roots, and places where land tenure is so unstable that only portable gardens are attractive.

Such areas were a natural challenge for us, since one of ECHO's purposes is to help people grow food under difficult conditions. There are few "soils" worse for gardening than a cement slab, a pile of rocks, a corrugated roof or a mass of tree roots. Since 1982, ECHO has been working on methods for gardening in such situations.

There is a major difference between ECHO's techniques and those used or contemplated by planners for most rooftop gardens in wealthier countries: the techniques described here can be done at a fraction of the expense that is normally considered necessary; they do not require specially engineered buildings to make sure that the roof can handle the weight of the soil. Gardens can even be grown on the edge of a tin roof of a shanty.

OVERVIEW OF ABOVE-GROUND GARDENING

Some Criteria for Above-Ground Gardens

- **Very low weight per unit area**

  This will not be a factor if the garden is not located on top of an unsubstantial roof or if it is placed on some other solid, study structure, e.g. if it is on a large flat rock or in a container sitting on the ground.

- **Inexpensive–almost no cost; preferably based on recycled materials**

  Because gardens made from recycled materials are often free or nearly free, this has obvious merit for any of us. Even if money is no object, it is satisfying to know that our container gardens have made minimal negative impact on the environment.

- **Satisfactory production with minimal inputs**

  Our goal is to get good production that meets these six criteria, not to try to match the high producing commercial hydroponic gardens.

- **No energy or moving parts needed**

  Electricity in some situations in developing countries may not be available, or power outages are frequent.

- **Made from local materials (not imported)**

  This is very important in economically developing countries where imported things are almost always expensive.

- **No instruments or analyses needed**

  Commercial hydroponic systems are incredibly productive, but such high levels of production require monitoring and adjusting nutrient levels. Neither the poor nor the North American homeowner wants to bother with this level of technical detail.

Requirements for Healthy Plant Roots

The roots themselves require a constant supply of only three things. I am assuming that other conditions for plant growth are met, such as sunlight, appropriate temperatures, and a means of support. The three things roots require are:

- a constant supply of **air**
- a constant supply of **water**
- a constant supply of **nutrients**

It is also necessary to provide a means to:

- keep the sun and wind off of the roots
- provide a space where the roots can grow
- support the growing plant (in some cases)

That's it. Note in particular that the roots of most vegetables do not require soil, potting mix or a deep container. In fact, the place where the plants grow can be so shallow that it is almost a two-dimensional "container," e.g. a piece of cloth. Really large plants like trees and shrubs would of course require a larger volume in which to grow and support the plant.

A Look at Four Above-Ground Gardening Methods

[Please note: one inch (1") = 2.54 cm.]

1. **The Shallow Bed Garden** is typically a 3–6" bed of compost. If the roof is quite limited in the weight it can bear, then either no soil is used, some lightweight material is mixed with the soil, or the bed is very shallow. Such beds are fertilized and covered with at least a thin covering of compost or soil. If compost is not available (a likely situation), plants can be successfully grown in fresh organic matter of many kinds. Almost any vegetable can be grown in shallow beds. Once the beds are established, they are like regular gardens except in their need for more frequent watering.
2. **Tire Gardens** are portable shallow bed gardens that can literally go almost anywhere. The garden is made from an old tire and a small sheet of plastic film (e.g. a garbage bag). Construction is simple and elegant. Lay a tire flat on the ground. Note that the top rim is a mirror image of the bottom rim. With a sharp knife or machete, cut off the top rim or tire sidewall. Place a piece of plastic inside the tire on the bottom rim, large enough so that an inch or two of plastic stands up along the walls of the tire. Now turn the top rim that has been cut off upside down. It fits like a lock on the bottom rim, holding the plastic firmly in place. Fill with growing medium, usually starting with lightweight, airy materials on the bottom and soil or compost on the surface. If the plastic is trimmed to near the bottom of the tire, the garden will essentially be a portable "shallow bed garden." If the plastic is left so that a pool of water is formed, it will be more like the "shallow pool garden."
3. **The Shallow Pool Garden** consists of a shallow pool of water 0.5–3" deep. Usually a sheet of plastic of the desired size is formed into a pool by laying sticks under each of the sides. Shallow beds made of any material that does not tend to become waterlogged are then built in the pool, extending at least 2" above the water line. The length of time between waterings can be extended by making a bucket waterer. [To make a bucket waterer, drill a 3/8" hole into the tight-fitting lid of a 5-gallon plastic bucket, about 1 inch from the edge of the lid. Fill the bucket with water (optionally containing a soluble fertilizer) and place it upside down in a cleared spot in the "pool."] Place a stick under the bucket lid at the point nearest the hole to allow air to enter under the bucket. This results in a constant shallow pool of nutrient solution in the bed, the depth of which is determined by how much the stick raises the edge of the bucket.
4. **The Wick Garden** consists of a piece of polyester cloth (the "wick") laid out on a flat area in the shape of the desired garden and a 5-gallon bucket waterer (see above) placed directly on the wick. Set the root balls (the roots and soil attached to plants in their starting containers) of transplants directly on the wick. Finish the beds by filling in around the plants to a depth of 3–6" with some extremely airy material such as pine needles, pieces of coconut husk, or even cola cans. It is important that this material be something that will not become waterlogged. Leave a section of the cloth clear to hold the upside-down bucket. The wicking action of the cloth spreads water and nutrients to the roots, which grow above and below the surface of the cloth. Sometimes the cloth is first covered with a thin layer (0.5–1") of compost or potting soil. Best results are found with short or trailing vegetables and herbs, such as onions, radishes, lettuce and mint.

Benefits of Above-Ground Gardening Techniques

Tire gardens on wooden posts in Haiti. (Note that tires are turned inside out, which provides greater growing area.) Photo by Danny Blank.

Protection From Animals and Floods. I have seen shallow bed gardens on platforms used in some countries to reduce the chance that chickens will destroy the young plants. It can be especially helpful to locate a seedbed on a platform for producing seedlings for transplanting into the garden. Development workers in Kiffa, Mauritania, at Rancho Ebenezer in Masaya, Nicaragua and near Hinche, Haiti have found a lot of interest in adapting tire gardens for similar purposes, placing tires on structures made from poles.

There are substantial areas near the Amazon River in Brazil where most gardening is done in shallow beds on platforms. In flood-prone locations the advantage is obvious, but platform gardens in the region are a primary gardening method even where it never floods. Some say that they plant gardens on platforms to avoid damage by small animals. Wayne Smith wrote ECHO, "They make a 4–7 foot long platform of sticks, an old canoe, etc. They place a layer of dirt and ashes/cinders on top, and then grow mainly green onions." I have also heard that some farmers of Mayan descent in southern Mexico use the same technique.

Gardens for the Handicapped. Any of the garden types we have discussed can be constructed on top of some sort of platform, making gardening available to people with physical handicaps that prevent them from working in the soil. If platforms

are placed at the right height, people in wheelchairs can garden easily. The platforms can be constructed of inexpensive materials because the gardens weigh so little.

Avoidance of soil-borne problems (e.g., diseases, pests, extremes in pH). Root-knot nematodes are such a problem in Florida that some susceptible plants cannot be grown unless the soil is first sterilized. However, some fungi that live on decaying organic material also kill nematodes. If we have enough organic matter in the soil we can sometimes get around the nematode problem. If we have 100% organic matter, as in some shallow bed and hybrid garden designs, or no soil, as in the wick and shallow-pool gardens, we have no root-knot nematodes. After a few growing seasons, however, the decay process is essentially over. At this point the nematode-killing fungi may no longer be present and nematodes can again become a problem, unless the bed is renovated with fresh organic matter.

Examples of some plants that are highly susceptible to root knot nematodes include squashes, cucumbers, green beans, and peas. Some vegetables produce a useable harvest in spite of being heavily infected, as can be seen by looking at the roots. Examples that come to mind include okra, tropical pumpkins, and winged beans. These plants may give a reasonable yield but may die prematurely and, when pulled from the ground, display roots heavily covered by the characteristic knots. Some vegetables in my experience seem to be relatively unaffected by root knot nematodes, though I cannot say that they cannot be harmed by them. These include corn, sorghum, onions, tomatoes developed to be nematode resistant, cabbage, kale, collards, garlic chives, and many herbs.

There may be other serious problems with the soil that may lend themselves to above-ground gardening, even in rural areas. For example, the soil may be exceptionally acidic or alkaline, be too sandy or have too much heavy clay, or be filled with rocks. In some urban areas the ground may have high levels of heavy metals as a result of pollutants over the decades falling to the ground in rainfall or just settling out as the winds blew them over the garden.

Ability to Garden in the Shade of Trees. Many heat-sensitive plants thrive better in some shade in the hot tropics. Above-ground techniques can be used to make beds on a sheet of plastic under trees. Any material that has no cracks or holes through which roots can grow can be used to make a bed that is unaffected by nearby tree roots. Benefits are that tree roots are not damaged by tillage; the plastic prevents them from interfering with the vegetables; and many plants benefit from light shade. Tire gardens are especially adaptable and can be placed anywhere that provides enough light, even directly on protruding tree roots or on a pile of rocks.

Limiting Factors in Above-Ground Gardening

It is not difficult to list possible problems with above-ground gardens.

- The poor may live in homes with rooftops that cannot even bear the weight of a person.
- Those (presumably the wealthier) with the most substantial rooftops may have the least incentive to garden on them.
- Fertilizers may not be available, especially fertilizers that contain micronutrients.
- People may not be prepared to give daily care to a garden.
- It may be difficult to develop a uniform formula for making the gardens when only recycled materials are considered.
- Water may be scarce or have to be purchased.
- Compost is usually not available unless people make their own, and motivation to do this may be lacking.
- Urban gardening projects in general have a reputation of little payoff among many in the development community.

There are situations where any of these problems may be critical. However, the world is a very, very large place. If a certain technique is only suited to one percent of urban areas we are talking about millions of potential gardens. A creative mind and innovative and can-do attitude is helpful to see successful above-ground projects develop. An idea that, if successful, promises to make acres of prime, presently unused, arable “land” suddenly available for producing food and some income, is deserving of extra effort. We can begin with those thousands of situations where the above problems are not limiting, while we consider how to include more people in growing their own food.

Special Considerations

It is imperative that your first community project succeeds. Do not involve many people in above-ground gardening until you are sure you know what will work and have done it yourself for at least one season. The success of the first community

project is more important than saving money on every possible ingredient. I think particularly of fertilizers. A common question is, "Why not use compost or manure 'tea' instead of fertilizer?" It is possible, but it is far from foolproof. If a gardening system is based on manure as the primary fertilizer it is almost certain that some gardeners will fail not because the methods themselves have a problem but because of inadequate amounts of some or all of the essential nutrients in the compost or manure tea. It is quite possibly cheaper (and certainly less offensive to the neighborhood) to use fertilizer than to haul in manure from the countryside. But more importantly, if it fails you will probably not get a second chance with the people who tried your "far out" idea of above-ground gardening.

Consider the market before promising people that they can make money on their gardens. A Colombian organization developed a shallow bed/hydroponic system with many similarities to what we discuss in this chapter. The project used donated rubbish–rice bran from a mill and wooden crates from an automobile parts shop–and recycled polythene from commercial flower farms. In addition to what the 130 participating families themselves used, the cooperative sold over three tons of vegetables each month. ECHO was never able to make contact with the project directors. We heard that the project ended once the funding stopped, due to difficulty in obtaining the hydroponic nutrients. While it was operating, a key factor in its success was that when each garden was planted, the market for its produce was guaranteed. This no doubt took a lot of leadership to provide the quality control and regular supply required by a supermarket contract. But even lacking such leadership, the vegetables can still be grown and eaten at home or sold in the informal marketing system.

TECHNICAL DETAILS OF ABOVE-GROUND GARDENS

The Shallow Bed Garden

It is hard to beat a well-made raised-bed garden that has good soil mixed with plenty of compost and receiving just the right amount of rain. If the only place for a garden is on a rooftop or a paved driveway or large flat rock, then using the same soil and compost to create a deep bed on the hard surface will give very similar results as they would in your garden. (However, you may need to add water more often than if it were a raised bed in a garden because the roots of some plants may normally grower deeper into the soil in search of water than the depth of your bed on a solid surface will allow.)

One needs to be more creative though if: (1) it is important to keep the weight at a minimum because it is on some structure such as a rooftop that was not designed to support the weight of the garden or (2) if there is no good soil available, compost is in scarce supply and people cannot afford to purchase a commercial potting mix to use in making a bed.

The most straightforward way to create a garden that weighs less is to make a planting bed with much less material than in a conventional garden—in other words, to make it shallower. ECHO refers to these as "shallow bed gardens." I very loosely and subjectively define "shallow bed" as meaning any bed whose depth is less than you might formerly have thought necessary. They can in fact be incredibly shallow if someone is prepared to add water several times a day, or if one devises a means to slowly add water throughout the day. The thickness of these beds is limited only by the logical condition that they must be some minimal thickness, perhaps half an inch.

What Plants Will Grow in a Shallow Bed?

We have had success growing a wide variety of vegetables in shallow beds. Some examples include amaranth, broccoli, cabbage, cow peas, corn, eggplant, cucumber, green beans, herbs (rosemary, tarragon, basil, sage, mints, chives, garlic chives), cabbage, collards, broccoli, kale, kohlrabi, lettuce, okra, onions, Lagos spinach, radishes, edible-podded peas, tomatoes, winged beans, sweet corn, yard-long beans and a variety of flowers.

It is easier to say what crops may give problems. We stay away from large vines that have such a large leaf area that they quickly deplete the reserve of water in the shallow bed, such as tropical pumpkins, watermelon, jicama or sweet potatoes. The shallow pool or "hybrid" methods described later may be better for these large plants; however, with sufficient volume (with either a deeper bed or fewer plants in a bed) or more frequent watering, there should not be a problem growing these larger leafed plants, letting them flow over a rooftop, down the side of the building, or over rocky soil.

Root crops require deeper beds. We have grown acceptable carrots in grass clippings, but had to make the bed about 8 inches deep. The bed shrank so much during the growing season as the grass clipping decayed that the carrots stuck out of the top by an inch. Carrots grown in a 3-inch deep bed had L shaped roots because the bed was too shallow. Carrots grown in wood chips were distorted because of the twists and turns the taproot made to avoid wood chips become the permanent shape of the carrot. This does not seem to be a problem with radishes though.

Choosing the Material for the Shallow Bed Garden

Fortunately in constructing shallow beds we can consider almost any growing medium because the weight is not much of a factor if the bed is not very deep. At ECHO we have tried beds made from whatever we could think of to see what would happen, e.g. regular soil, compost, woodchips, sand, gravel, grass clippings from lawns, corncobs. Had we been in a tropical country we would also have tried things like rice hulls, shredded coconut husks, sugar cane bagasse (what is left after the juice is squeezed from the cane), coffee pulp, etc. We found that we could grow plants in any of these, but not all were equally good. I was especially surprised at how well many vegetables did in a shallow bed of grass clippings.

Professor B.D. Cotton, an ECHO volunteer from England mentioned that in England and other European countries it is very common to grow vegetables in plastic “grow bags” filled with well-rotted manure, peat, compost or some commercial potting mix. These would fit into the category that I would call shallow beds.

You should experiment with mixtures. When possible, if compost is not available, we like to use a mixture of different kinds of organic matter (dead plants) and perhaps inorganic materials. Mixtures are especially good because you have more flexibility to create the kind of environment that roots like. It is also likely that if a needed nutrient is not released as one component begins to decay, it will be by another. You can include many common garbage items.

A bed made from grass clippings and cola cans turned out to have some special advantages. Such a bed can be several inches deep but still not too heavy, enabling larger vegetable plants to grow without special support. This bed is constructed using approximately 40% by volume cola cans (with slits cut into the sides so roots can enter that well-aerated and hopefully humid interior). The other 60% is grass clippings mixed between and placed on top of the cans. Ordinary garden fertilizers may be added if necessary. We added the cola cans when we found that making a grass clipping bed deep enough to support taller vegetables heated up, due to rapid decay, to a greater extent than is good for plant growth. Also due to decomposition, the beds shrank into a rather shallow bed that became so dense that the roots could not get enough air. A variety of okra that grows to perhaps four feet tall produced well in the grass clipping and cola can bed without any special means of support. We have not tried this again. If you experiment with this technique, let us know what happens. An alternative to cola cans might be pieces of coconut husk placed positioned so that there were air spaces under each piece.

A bed made from a 2–5 inch layer of weeds packed closely together and covered with perhaps a couple inches of grass clippings or, even better, compost from a previous bed works well. A 6–8 inch deep bed for corn/maize was made in this way. A benefit to placing weeds on the bottom (rather than grass clippings, for example) is that there are more air spaces between the weeds, which is better for roots.

Once you have settled on the materials for garden construction, the available fertilizers, and the vegetables to be grown, you will be able to develop straightforward, detailed instructions for your unique system of shallow bed gardening. That is what you will pass on to new gardeners in your community.

Constructing the Shallow Bed

No Container is Necessary. An important factor that makes these beds inexpensive is that no container is necessary. Depending on the material used, sides may not even be needed, especially if mulch is placed on top or at least on the edges of the bed. Sides are only necessary if the garden is placed on a platform or table of some sort where the garden extends right to the edge of the structure, or where appearance is important. We have had a lot of heavy rains and strong winds over the years, but the only bed that gave us a serious erosion problem was one in which we used a large amount of silt from the bottom of a fishpond.

How wide and long to make the bed? The shape of shallow beds is determined by the same considerations that one uses in making raised beds. They can be of any length, but a break for a path every 8–12 feet is helpful. They should be just wide enough (4–5 feet) so that a person can reach to the middle of the bed from either side. Thought should also be given to maximum use of space. A path down the length of the rooftop with beds and aisles going off to either side might be the most efficient.

How deep should the "shallow" bed be? Like most people, when I first began thinking of gardening on rooftops I envisioned gardening in rather deep containers. Container gardens, however, can be heavy and moderately expensive. If they are too small, larger vegetable plants may grow but give little produce.

Roots do not require much volume when there is plenty of water and nutrients. Why do roots normally cover a much larger volume? When watering is sporadic, a large volume of soil (with roots throughout) is required to hold enough water to keep the plant supplied between waterings. The primary question about how thick the shallow bed must be comes down to this: How often are you prepared to water?

Often people wrongly assume that only shallow-rooted plants will thrive in a shallow bed. Except for tubers where the edible part exceeds the size of the bed, we have not found this to be true. Although a shallow-rooted plant cannot take advantage of a deep bed (its roots will not reach to the bottom), a deep-rooted plant can adapt to take advantage of the space in a wide but shallow container.

A shallow bed garden on a roof is usually a bed of perhaps 3–6 inches. If there were no other considerations, an above-ground bed that was perhaps 9–12 inches would be about ideal. That is more than sufficient to support even tall plants like sweet corn and to encourage plenty of root growth for even the most demanding of plants. For most rooftop applications, however, the bed will probably need to be shallower than this. A bed half that deep would have the advantages of weighing half as much and requiring half as much material to be located and moved to the roof to make the bed, then removed from the roof if plans later change. The biggest disadvantage is that the maximum amount of water the bed can store is half as much as in the one twice that deep. This means that it will need to be watered twice as often. A bed a tenth as deep would hold only one tenth as much water and need to be watered ten times as often, and so on. Ultimately one could end up with a bed of perhaps an inch or less that might need to be watered several times on hot, sunny, windy days if there was a big leaf area through which a lot of water was being transpired into the atmosphere.

Begin with a sheet of plastic. If a sheet of plastic is available, we like to place it on the roof surface and then build the garden on top of the plastic. People are understandably hesitant to place the garden bed directly on the roof surface because of the danger of damage to the roof. Roots might grow into any cracks that might be in the cement and eventually make them larger. Placing the garden directly onto a cement rooftop might cause minor discoloration. The plastic should eliminate both problems. If there are substantial cracks already in the cement roof, water might seep through to the ceiling below. The plastic should minimize but not eliminate this possibility. No doubt it will always be moist under the plastic, but that is less of a worry than a considerable supply of water and roots in direct contact with the roof.

Pat Lahr, a missionary in Haiti who has done a lot of work with urban gardens, found that the roof surface stayed constantly wet under the plastic, though there was not a lot of water. Without plastic the roots would occasionally dry the beds and hence the roof surface under the beds. Whether there is any benefit to having occasional dry surfaces is doubtful and the risk of roots growing into cracks would seem to be more of a problem.

Place materials on the plastic to make the bed. Look for materials that are light weight and easily obtained at little or no cost, such as wood chips, rice hulls, sugar cane bagasse, or grass clippings that have spent several weeks in a pile (more on grass clippings below). You can place pulled weeds in the bed as long as they are covered with enough soil that they will not germinate. Avoid plants such as Napier grass (elephant grass) because the stems readily sprout and grow.

Arrange the materials to form the bed, then thoroughly wet the bed. If you notice that water doesn't tend to adhere to the surfaces of the material you are using, as often happens if the materials are quite dried out, add a tablespoon or so of dish-washing or laundry detergent (any variety) to the watering can and pour evenly over the surface. Detergents fall under a class of compounds known scientifically as wetting agents or surfactants (surface-active-agents). They help water adhere to surfaces. This will help keep the materials constantly moist, and so hasten decay. It is also important that the particles composing the bed be easily wetted because the roots that will begin growing in the bed will get much of their moisture from the surfaces of these particles.

You can transplant seedlings directly into these beds. However, you may find that seeds do not absorb enough moisture to germinate, or tend to try out between waterings. See the section below on "Planting in the new bed."

Make the initial bed of grass clippings deeper than what you want to end up with, to allow for shrinkage during the initial preparation and continuing as the bed decays. It might take a foot of fluffy grass clippings to end up with one to two inches after the first cropping season.

Some special techniques for using grass clippings to make a Shallow Bed Garden

We place grass clippings in large piles (perhaps a meter across and a meter high) until needed. Within a few weeks the pile will have heated up and considerable decomposition will have begun. Also we believe (no data) that most pesticides that might have been on or in the grass clippings are likely to be destroyed during this time of elevated temperatures caused by high biological activity.

If the pile of grass clippings is not too old, the contents will be fluffy and moldy. When you dig into the pile spores from the molds growing in the pile may move into the air almost like smoke. (Be careful breathing these spores. I have developed quite an allergy to the mold, though only one other staff member at ECHO has reacted to it.) If you leave it too long after it reaches this fluffy stage, the pile shrinks and becomes dense and wet and difficult to work with.

Thoroughly wet the pile. Often the clippings do not want to absorb water–even after adding a lot of water, the clippings half an inch below the surface may be dry. If that happens, wet the pile with detergent in the watering can as previously described. While adding water, walk over the bed to compress the fluffy grass as much as possible. We want to end up with plenty of air space, but we also need the bed to be sufficiently dense to have ample moisture in the vicinity of the seed and roots.

Add fertilizer. We add an ordinary garden fertilizer and dolomitic limestone. If it is 10-10-10 fertilizer, we add 5 pounds per 100 square feet. We did not arrive at this amount by careful experiments. It works, but you can do your own experimentation to see if less would work or if more would be better for the materials you are using to make the bed.

The numbers refer to the percent of nitrogen, phosphorous and potassium, respectively. If it is 5-5-5, we add twice that amount, etc. Neither the exact numbers nor the exact amounts are that important. There are many other fertilizer formulations on the market. You might only be able to get something like 8-6-10, for example. Don't worry about it. Just avoid extremes like 36-10-10, a very high nitrogen fertilizer used for lawns, or something like 10-0-10 which would be a special purpose formulation completely lacking in phosphorous.

We always use fertilizer with micronutrients (that is elements needed only in minor amounts). If you cannot find that kind of fertilizer but are making the bed from organic materials, the micronutrients that will soon be released by the decaying organic material may be sufficient. One can often buy micronutrient formulations separately and inexpensively. These would be used in small amounts, following directions for a regular garden. Added micronutrients are a must with any system that is not based on organic matter, e.g. sand or gravel.

A quick way of providing these micronutrients, if they are not contained in the fertilizer, is to apply some manure or to water the garden with a manure tea made by soaking a bag of manure in a barrel of water for a few weeks. To avoid "salt burn", experiment with varying amounts of water used to dilute the manure tea. Realize that the manure or manure tea may not have an ideal ratio of the each micronutrient, and might even be totally lacking in one or more. If that happens, the plant will develop symptoms of micronutrient deficiencies which usually appear on the younger leaves first. Check on the web or in a library to learn what symptoms the deficiencies of various micronutrient look like. Often they involve discolorations of various kinds (e.g., yellow or white leaves, reddish color in veins, etc). You may be able to identify what particular nutrient is lacking and overcome the problem by adding only that one nutrient.

What else can be used to make the bed? Jeff McManus wrote from Bangladesh after reading about rooftop techniques in *ECHO Development Notes* to tell about how local gardeners grow vegetables in beds on top of the ground made from water hyacinth. Water hyacinth (*Eichhornia crassipes*) is one of the most prolific plants on earth. This floating weed chokes waterways around the world. He wrote that people in Bangladesh clear their ponds and rivers of the floating plants and pile them on the banks. They plant vegetables in the water hyacinth piles and these mounds become "floating gardens" in the monsoon season. The McManus family grows lettuce, papayas, tomatoes, and very productive roses in boxes filled with water hyacinth harvested from nearby nutrient-rich waters. They chop the plants into small pieces, let them compost for two weeks with daily turning, and plant directly in the compost. McManus mixes the compost with a little manure and some wood shavings, but does not add extra fertilizer, since the water hyacinth is an efficient collector of nutrients. The spongy plants hold a lot of water, so very little watering is needed for awhile. The box gardens work best with fresh material; reused compost seems to promote diseases in the plants.

ECHO collaborated in the 1990's with a US NGO, Center for Citizen Initiatives, and Russian colleagues to show what could be done in rooftop gardening in St. Petersburg, Russia. The "shallow bed" gardens we used there were bags of peat that had been used for a few years in a large greenhouse complex. They replace the bags periodically to ensure that they get the highest possible greenhouse yields, so the bags and peat only cost US$0.50. We cut the tops off, added dolomite and fertilizer with micronutrients and had very successful gardens. We also found a useful ingredient to incorporate into rooftop beds that is manufactured in Russia for insulation in buildings but is also used by nurserymen. This man-made product reminded me of lightweight volcanic rock, except that the largest particles were no more than half the size of a pea. Their name for it is "keramzit." I have seen a similar product in the USA, perhaps manufactured for growing orchids.

Planting in the New Bed

Planting seeds or transplants into shallow bed gardens made of compost is done as in any other garden. Planting directly into beds of organic material that has not yet decomposed requires some special techniques. Larger seeds like peas or beans can usually be planted directly if the medium is made of a material that packs closely enough together to remain moist most of the day and make close contact with the seed to keep it wet. Seeds must be deep enough into the medium to remain moist but shallow enough to be able to grow to the surface after germination. The top inch or so of many materials, e.g. nearly fresh grass clippings, tend to dry out. You may need to water a few times each day until they germinate. We have also had the opposite problem with older, matted grass clippings, which stayed too wet.

Smaller seeds, like carrots, require compost or soil or something of very similar texture to get started. You can cover the entire bed with compost or soil or just form a 1–2 inch deep trench in the packed down grass clippings, fill it with compost or soil, and plant in this trench. Even this small amount of compost will provide an environment for the seed and initial roots that is just like they would experience in any garden. A useful technique for germinating carrots in any garden is to place a board on top of the row. This ensures that the top layer (¼ to ½ inch) of the soil remains moist. Look under the board daily until you see the first seeds germinating, and then remove it.

Transplanting likewise can demand special care if the medium is not similar in texture to soil. If the bed is made of undecayed plant material that does not pack well, we either cover the top with 1–2 inches of soil/compost or make a small hole, insert the transplant, and fill in around it with several handfuls of compost or soil.

Keep a close watch on the appearance of the vegetables. At the first sign of nutrient deficiency, add a bit more fertilizer. With high-nitrogen materials like grass clippings, this may only need to be done once or twice, or not at all. With low nitrogen materials like wood chips or straw it will be necessary to add fertilizer frequently. A small amount of solid fertilizer can be sprinkled around the plants, taking care not to get it in direct contact with leaves or stems. Our wood chip gardens produce best if they are watered every other day with a solution of soluble fertilizer or manure tea. Most soluble fertilizers are made to pour directly on the leaves (some nutrients can be absorbed through the leaves of some plants). This is especially helpful if a deficiency has already appeared. If possible have a spray bottle on hand filled with a soluble fertilizer. Use it as "medicine" to spray plants when any deficiency appears. *Do not spray manure tea onto the plants because they may contain disease microorganisms!*

Refurbishing the Shallow Bed in Subsequent Seasons

You may be surprised at two things: (1) how quickly the depth of the bed drops as the material turns to compost and (2) how quickly beautiful compost is formed. If there is no soil in the beds, just organic material, the material eventually turns deep black and may eventually look something like peat. The bed must be refurbished after harvest whenever it has shrunk to less than the desired depth or has become so dense that it holds too much water and too little air. Alternatively, the bed can be recycled: dismantled and the compost which has formed in it used as the top layer in constructing new beds.

If the bed is still deep enough for another growing season, the only refurbishing needed is to apply fertilizer. Much of the bed, depending on its original composition, may by now have been converted to compost. The bed should not need as much fertilizer as it did when it was first constructed and planted and possibly may not need any addition of fertilizer, depending upon whether the now-decayed organic materials have turned into good compost that provides all the nutrients needed for healthy plants. This is not a delicate system, like hydroponics, with exacting fertilizer requirements. I trust that any frustration at not finding rigorous details on the amount of fertilizer will be more than compensated by having a bed that allows some flexibility. More fertilizer will be needed if you have heavy rains that leach away nutrients. Learn what each of the vegetables or flowers that you grow look like when they are well grown, then watch for clues about what they may need from time to time. You may be able to find pictures on the Internet of what various nutrient deficiency symptoms look like for the particular plants you are growing.

If the original organic material has completely turned to compost, then within one or two growing seasons the bed should be remade. The new bed will be easier to make than it was to make the original bed, because we are now starting with a considerable amount of compost. Rather than layering new organic material, e.g. grass clippings, on top of the bed, it is best to remove the composted material, layer the new undecayed material onto the place where you want the bed, then place the remains of the old bed back on top. We add some fertilizer (less than with a totally new bed) and water.

There are two reasons to refurbish in this way. First, the older material can become so dense that, if left at the bottom of the bed, aeration might be poor. This is not a problem when it is placed on top of the less compact fresh organic material. Second, it is much easier to plant into the composted material than it would be into the fresh material.

How Much Does a Shallow Bed Weigh?

We place great emphasis on developing very lightweight beds for rooftop applications. That is why we normally do not use soil and try to keep the depth to no more than three inches. Individual soil particles typically weigh approximately 2.75 times as much as an equal volume of water. There are spaces between the tiny soil particles, however, which can account for up to 50% of the volume of a good garden soil. It is the worst case (heaviest soil) that concerns us in considering any possible danger to the roof, so we will consider the weight after a drenching rain and assume that every space is filled with water. Such saturated soil weighs 1.9 times as much as an equal volume of water. Individual particles of organic matter typically weigh slightly more than water (1.1 to 1.4 times) and the spaces between them are much more than 50% of volume. So in a worse case, i.e. a totally flooded bed of fully decayed, compact organic matter, the weight would be at most 1.2 times that of water. In most cases, the weight will be almost the same as an equal volume of water.

The weight can still be considerable. This table compares the weight of 3” (7.6 cm) and 8” (20.3 cm) deep beds that are 4 feet wide and 8 feet long (1.22 m x 2.44 m), one with soil and one with well decomposed organic matter, both fully saturated with water.

Maximum weights of four rooftop gardens, each 4 x 8 feet (1.2 x 2.4 meters).

Depth	Weight	
	Decomposed Organic Matter	**Garden Soil**
3 inches	598 lbs (272 kg)	947 lbs (430 kg)
8 inches	1,595 lbs (725 kg)	2,552 lbs (1,147 kg)

At ECHO we usually have no sides to the gardens in order to keep material cost to a minimum. If cement block sides were used, the weight and cost would be considerably greater. Based on what we have seen, people are often more cautious than necessary. If there is any doubt about safety, remember to put the heaviest items (like a barrel of water) directly over walls.

Tire Gardens: A Special Adaptation of Shallow Bed Gardens

The tire gardens are the “jeep” of above-ground gardening methods: portable gardens that can literally go almost anywhere. I met with some potential rooftop gardeners in El Salvador. After showing how to construct the garden, it was fun watching as their imaginations led them to move a tire garden to unlikely places for a garden: on a flat rock, on a steep hillside supported on the downhill side with rocks, on the roots under a tree, on a pile of rock or a junked car.

If there is danger of theft or damage by chickens and goats, the tire can be placed on top of something, even along the edge of the tin roof of a shanty. People often put pieces of iron or other heavy items on the roof of a shanty to keep it from blowing away. They do this because there is not enough framing to adequately secure the corrugated roofing. A few tire gardens might even help the roof stay in place.

The tire garden can be moved if necessary as seasons change. A growing vegetable may need to be moved where there is more sun or less sun or where there is less wind. If the garden is on a rooftop, it can be placed on sticks or stones so that air can circulate underneath, keeping the roof surface dry. If gardeners themselves have to move, they can take their gardens and their improved soil to their new home.

There is less potential to damage the roof. Though the shallow bed garden can be constructed easily on any sturdy flat rooftop, there are situations where this causes concern. Some cement rooftops may have small cracks. There is fear that because of the constant moisture and fertilizer beneath the garden, roots will begin to grow into the cracks. Nature shows us how this process can even break rocks as the roots expand.

For this reason, when presented with a range of possible garden construction methods for rooftops, many citizens in developing countries will choose the tire garden. The tire can be placed on three or four sticks, rocks or other items so that there is considerable air space beneath the tire. This allows the air to circulate and eliminates constant dampness. Also, there is no contact of the roots with the rooftop itself. Construction is simple and elegant and may cost nothing. What we want to end up with is a portable growing container that can be placed anywhere and moved if necessary. The bottom that will hold the potting mix in the container will be a piece of ordinary plastic, e.g. like painters use to keep paint from splattering on the floor. The plastic could even be a thick garbage bag. Lay a tire flat on the ground. Note that the top rim is a mirror image of the bottom rim. With a sharp knife or machete or large-tooth saw, cut off the top rim or tire sidewall.

Place a piece of plastic inside the tire on the bottom rim, large enough so that an inch or two of plastic extends up along the walls of the tire. Now turn the top rim that you just cut off upside down and place it inside the tire where it will fit like a glove against the bottom rim, holding the plastic firmly in place. If the plastic is trimmed to near the bottom of the tire, the garden will essentially be a portable "shallow bed garden." If the plastic is left so that a pool of water is formed, it will be more like the "shallow bed in a shallow pool garden" that we discuss later.

Any suitable soil, compost or potting mix can be used to fill the tire. You will need to judge if fertilizer is needed and when it should be applied, based on what you use for a planting medium and how plants are growing. At ECHO we sometimes place an empty flower pot or a PVC pipe in the center so that we can see how much (if any) water is standing in the bottom and so judge when to water. More often though, we make sure the plastic does not retain too much standing water and we treat it as a straightforward shallow-bed container garden. We usually incorporate something with a lot of air space into the planting medium to reduce the weight of the tire garden. The same amount of planting mix goes farther because of the air spaces. At ECHO we sometimes use cola cans with holes cut into the sides so roots can penetrate the can. In the tropics one could use coconut husks or possibly pine cones or very light weight volcanic rocks.

In summary, Shallow Bed gardens or hybrid gardens that include a shallow bed, are the most foolproof of the methods we have tried. Especially when made of compost, it differs little from gardening in the soil. The main differences are its need for daily watering and that its limited depth permits only shallow roots (to which plants show a surprising ability to adapt). The ability to grow vegetables in fresh organic material while it is being turned to compost is a very attractive feature of the method.

One might be tempted to think that the need to water frequently would not be a problem if the garden belonged to an unemployed person who presumably had a lot of time on his or her hands. However, the limited feedback I have received suggests that human nature and demands on time even of an unemployed person are such that the likelihood of a gardening project succeeding is much greater if watering needs are less frequent than may be required for shallow bed gardening. That is especially true when the garden is located on a rooftop that may be difficult to climb on to.

This leads us to the benefits of the next gardening method that we call "wick gardens."

Wick Gardens

The wick garden was developed to enable people to have exceptionally shallow bed gardens without the need to water several times each day. Pat Lahr first got me thinking about using wicks for this purpose when I visited his rooftop garden in Haiti in the late 1980's.

You are most likely to think of a candle or lantern when you think of a wick, where kerosene or melted wax are pulled by capillary action up the wick from the pool of liquid below.

Water is likewise moved by capillary action if a cloth or fiber wick is placed in it. For example, if you wear blue jeans and stand in a quiet pool of water that comes to your knees, the water will slowly move up the leg of your pants well above the level of water in the pool.

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The wick for the garden can be any kind of cloth. For example the wick might be an old blanket, pieces cut from old clothing, a piece of carpet or a special fabric made for this purpose that is used in greenhouses to keep the soil in small pots moist until they are ready for sale. The garden can make use of a (1) vertical wick to move water upwards as in the example above of a person standing in a pool or (2) a horizontal wick, which is a piece of cloth lying on a flat surface, to move water that is placed on one spot toward all corners of the wick.

How thick does the wick need to be? We have found that very thin pieces of cloth may not be able to deliver enough water to areas farther from the bucket, especially on a sunny and windy day or after the plants have developed a considerable leaf area. Using the analogy of the wick as an irrigation pipe, a thin wick is like a small diameter irrigation pipe. Thick wicks or large diameter irrigation pipes can deliver more water at a faster rate. If the thickness of the wick seems to be a problem, you can try doubling it over to make it twice as thick with twice the water moving capacity or choosing a thicker piece of cloth.

Establishing a Wick Garden

Imagine that you have cut an old bedspread to the dimensions common for garden beds (let's say 4x12 feet) and have laid it on a cement slab. You have purchased some cabbage and lettuce plants in 4-inch pots and wish to grow them on this piece of cloth. What needs to happen for this bedspread to become a productive garden?

All you need to do is make sure that you meet the requirements for healthy root growth that we discussed earlier:

- **Air.** Whether the roots grow on top of, under or within the tablecloth, there is certain to be air. You could not keep air from any of those places even if you were determined to do so. You need to nothing further to ensure an abundance of air.
- **Nutrients.** You need to add nutrients either directly onto the cloth wick or dissolved in the water that you supply. You can save money by sprinkling directly onto the wick an "initial charge" of dolomite (dolomitic limestone), some ordinary garden fertilizer, and a small amount of a micronutrient mix. It is considerably less expensive to use these common fertilizers than to rely entirely on dissolving the more expensive soluble chemical fertilizers in the water as you add it. Water-soluble fertilizers cost much more to manufacture because special ingredients are needed to make sure they do not react with each other and become insoluble.

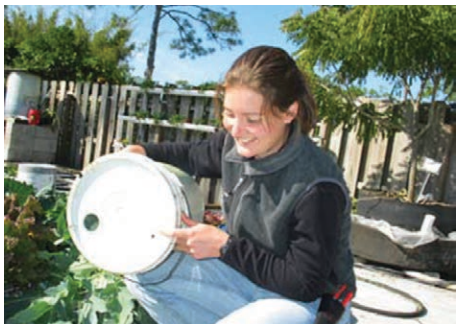
  An added advantage of having this "initial charge" of fertilizers is that they are less likely to be washed away by rain than soluble fertilizers. An inch of rain will wash away most soluble fertilizer that is in the bed, but this initial charge of ordinary fertilizer and dolomitic limestone will release nutrients for several days or weeks, or months if you buy what is called a "slow release" fertilizer. Slow release fertilizers are prepared with special techniques that cause the nutrients to dissolve little by little over a long time. This is a great advantage where there is no soil to help hold on to the nutrients, but they are quite expensive and not available in all parts of the world.

  Every time you water the garden, to every gallon of water dissolve between 1–3 teaspoons of a soluble fertilizer with micronutrients that has been manufactured for soilless gardening. If the plants seem to not be doing as well as you would expect with a teaspoon (5 ml) of fertilizer per gallon then begin using higher concentrations. Every gardener needs to learn to "read" the health of the garden. This comes with experience.
- **Water.** You must either frequently sprinkle water on the tablecloth or find some other way to keep it continually wet. Unless you have so much time available that you can water the garden, without fail, several times each day, then you need to find a way to automate some of the watering chores. But remember that we are trying to make sure our gardens are not dependent on expensive techniques that require technology and reliable electricity.

  This can be achieved by installing a very low technology system that will slowly release water to the wick as it is used up. Purchase some five-gallon buckets that have tightly fitting lids. I find that one bucket per 16 square feet is about right. Or go to a business that buys a lot of liquids in five-gallon buckets and might be willing to give the empty ones to you. For example, bakeries often buy jelly or cream filings in such buckets. Painters or plasterers discard dozens of five-gallon buckets on every job.

  Drill a single 3/8-inch (0.95 cm) hole in each lid. The hole should be located roughly an inch (2.5 cm) from the side of the lid. The bucket is filled with water that contains about a tablespoon of soluble fertilizer. You may purchase one of the soluble fertilizers sold to homeowners at garden centers, at farm supply stores for injection into irriga-

tion systems, or at greenhouse supply houses for hydroponic vegetable production.



Place the buckets where you want them. Experiment with number and placement of buckets needed to ensure even distribution of water. You might make a small barrier around each bucket in order to keep materials you will be adding from falling onto that spot while you are refilling the buckets. At ECHO we have used bricks or constructed a very simple barrier from wood or bamboo, but if the bed is made from materials that tend to stay in place (e.g., pine needles, this is not necessary).

Cover the wick to keep the sun and wind from drying the cloth and damaging plant roots. Roots that start to grow on top of the wick will likely be damaged by the direct sun. Furthermore, a wick in full sun that is kept wet with water that contains all the nutrients necessary for plant growth will quickly become covered by a green growth of algae. This will be unattractive, use up a lot of the nutrients, and will take a lot more watering because the sun and wind evaporate the water so much more quickly. A final problem is that if there are salts in your water, for example if the water is hard, these will be left behind along with any unused fertilizer when the water evaporates. This can build up and become harmful to the plants.

So you need to cover the wick with something, almost anything that isn't toxic, to keep the sun and wind off of the cloth and to keep the sun from damaging the roots that will emerge. ECHO has used things like pine needles, gravel, woodchips, recycled cola cans, or corncobs. Almost anything can do because the only purpose is to keep the sun and wind from the wick and perhaps to provide a little support-you could even use a pile of old shoes!

Planting the Wick Garden

This system works best if plants are transplanted rather than direct seeded. The basic problem seems to be that a seed sitting on a wet piece of cloth may not have sufficient contact to absorb the water needed for good germination. Very small seeds, such as lettuce, would be more likely to germinate than a large seed, such as a bean. We hope to do more experimenting with direct seeding. You might try placing a very small amount of soil over the seed or plant larger seeds in a small mound of soil that you place in the spot where the plant is wanted.

Thoroughly wet down the wick and whatever material is now covering the wick before transplanting onto it. Determine where you want to place each plant. Remove the first plant from the container. At the spot where you want the first plant, move the covering material aside so that enough of the wet wick is exposed that you can place the root ball in tight contact with the wick. Sometimes I gently push the bottom edges slightly outward to obtain even more contact between the root ball and the wick. Good root ball/wick contact is very important. Until new roots start to grow, the only water the root ball will receive is that pulled from the wick by capillary action. Gently replace the covering material around and a little above the root ball so that the sun and wind do not dry out either the wick or the root ball. Continue until the entire garden is planted.

Watering the Wick Garden

Having planted the wick garden, now fill each of the five-gallon buckets with water that has 1–3 teaspoons of soluble fertilizer dissolved in each gallon. Place the lid into which you previously drilled the 3/8 inch hole tightly on the bucket, turn the bucket upside down and set it on the wick. At ECHO we usually place three buckets in a garden this size, i.e. 4 X 8 feet, one bucket for every 4 feet. If you have more buckets you will need to refill them less frequently.

Water immediately begins to trickle from the hole and onto the wick. Wicking action (movement of water caused by capillary action) moves the water from under the bucket and continues to move it toward the edges of the garden. The cloth wick acts like an irrigation pipe, distributing water and nutrients over the entire area of the wick.

Why doesn't all the water run out of the bucket and off of the wick? The answer is that when the wick becomes thoroughly wet around the bucket an essentially airtight seal develops between the edge of the bucket lid and the wick. A vacuum builds up as more and more water leaves the bucket but is not replaced by air bubbling into the bucket through the small hole in the lid. The vacuum eventually becomes strong enough to support the weight of the water and prevent any more water from flowing through the hole.

Anyone who has watered chickens or a pet bird is familiar with this principle. For example, a jar of water with a hole in the lid can be placed upside down in a bowl with one side slightly raised by sitting it on a small object. Water will rather quickly run from the jar until it fills enough of the bowl that there is no access for air to enter the jar. A little more runs out until the vacuum stops it. As the chickens drink from the bowl the water level drops and allows a few bubbles of air to enter the jar, reducing the vacuum enough that some water can again flow into the bowl and replace what the chickens drank.

How often do you need to refill the bucket? That is one of most frequently asked questions and the answer must be vague. If the surface is flat so that no water flows off of the wick due to gravity, and if there is a good covering of the wick so that it does not evaporate, then the only way water leaves is when it is taken up by the roots. Some of that water will become part of the plant, but a great deal of it is evaporated into the air through the leaves. The amount that evaporates depends upon the leaf area, the kind of plant, the temperature, the humidity and wind speed (water evaporates faster when the humidity is low and wind is high), the degree of cloudiness, and intensity of the sun. (At ECHO the sun is almost overhead in June but at roughly 45 degrees from the horizon in December.) Finally, the species of vegetable being grown makes a difference. Plants that tend to be drought resistant that originated in semi-arid regions, have mechanisms that reduce the loss of water through the leaves. Other vegetables have little such ability and can wilt quickly. You can always supplement the bucket irrigation system by sprinkling water directly over the bed at any time.

As with so many other aspects of gardening, there is no substitute for an alert gardener who responds to the needs of the plants. Remember that there is really very little water held by the wick. If the buckets run dry, the vegetables you are growing tend to wilt easily. So if conditions favor rapid loss of water through the leaves, then you need to refill the buckets soon after they empty and perhaps use slightly less soluble fertilizer. If this is not possible, then consider adding another bucket. Be aware that some plants may develop so much leaf area, for example pumpkins that vine several feet away from the bed, that watering becomes overwhelming. In such cases a wick garden is not a good system for growing those plants. Try one of our other recommended bed designs that have a greater water-holding capacity.

Can manure tea be placed in the bucket as the source of fertilizer? Many people ask that. Could manure tea be the basis for a completely organic hydroponic system? Because the wick garden is based on subsurface irrigation via the wick, the tea would spread the nutrients directly to the roots, thus avoiding microbial contamination of above-ground parts of the plant.

Based on our limited experience, I believe it would be very difficult to provide all the needed nutrients in the right ratios based only on a manure tea. That is not to say that you could not come up with a process and formula that would work, at least for some crops. You would need to settle on a manure source that was uniform over time. For example, horse manure, chicken manure and cow manure differ greatly in composition. Old manure will differ from new manure. Seasonal differences that affect temperature will affect the mix of microorganisms and how rapidly they work. The nature of the feed the animal eats will affect the nutrient content of the manure and hence of the tea. It would be very difficult to develop a formula that many individual gardeners could use and get uniform results in vegetable production.

As a supplement, manure tea has value. You could add the initial fertilizers to the wick and then distribute manure tea through the bucket. You will have trouble with the 3/8-inch hole plugging up if sediment ends up in the tea. The bed could then quickly dry out. So keep a watchful eye on the system till you learn how it performs. If the vegetable is a tall plant where hand watering with manure tea would not put it in touch with the edible parts, then you could use a watering can.

Why does the wick garden work best during drier periods? As you can well imagine, an inch or so of rain can quickly wash away nearly all the dissolved nutrients when the garden is only a piece of cloth. So the wick method is best suited for gardening during seasons when rains are infrequent. Or you could cover the area with a plastic rain shield of some sort.

At any time of year, if it rains enough that you believe the nutrients may have washed away, you should replace them. All you need do is dissolve some hydroponic fertilizer in a watering can and sprinkle it over the wick. This is even more important if it rains several days in a row. That is because the hydroponic solution in the bucket only drains out when the wick begins to dry up. If the wick does not dry out for several days, the bucket may not be of much help, leaving plant roots only with water and air but no nutrients.

It you recently placed some of the less expensive field and garden fertilizer on the wick, it is likely that nutrients will continue to slowly dissolve and become available to plants. If by any chance you placed some of the far more expensive “slow-release fertilizer” pellets on the bed, they may release nutrients slowly over a period of six months or so.

Shallow Pool Gardens

Daily watering required by shallow bed gardens can be a problem. Pat Lahr, the "rooftop garden missionary" in Haiti that I mentioned previously, showed me several years ago how to use a five-gallon bucket to maintain a constant level of water in a shallow pool.

He used a principle that farmers have used for decades to automatically water animals. As we discussed in the section on wick gardens, only so much water can flow through a small hole in a closed container if there is no way for air to bubble in through the hole to replace the water. Without the bubbles, a vacuum builds inside the container and the water flow ceases until something happens that allows another air bubble to enter.

As with the wick gardening system, a 3/8" hole is drilled in the lid (one inch from the edge) of a five-gallon bucket. The bucket is filled with water and placed upside down in the pool. The water can have a complete hydroponic fertilizer dissolved in it if desired. The side of the lid nearest the hole is placed on a stick just thick enough to provide the desired depth of water. Water flows from the bucket until the pool of water rises to the point that air can no longer get under the lid and into the bucket. This ensures a continual, shallow pool of water. When the pool level drops enough to allow a few bubbles of air into the bucket, more water flows into the pool.

Two more things are needed if the shallow pool is to be used to grow plants. First, it is essential to keep the sun, the wind and mosquitoes from the water surface. The sunlight would damage the roots if it struck them directly. The sun and wind combined would rapidly evaporate the water and increase the concentration in the remaining water of salts (from the water source or from added fertilizer). The water would become dark green with algae growth (which would compete with plants for fertilizer). Mosquitoes would breed in the water, potentially causing the number of mosquitoes and mosquito-borne diseases to increase. Second, it is necessary to provide some support for the plants.

In ECHO's first attempt at building a shallow-pool, we used a six-inch layer of pine needles and hydroponic solution to grow an okra plant in a four-foot square shallow pool garden. Naturally, this did not provide much support for the okra plant and it fell over when it was two feet tall. However, with the main stem now lying firmly across and on the top of the pine needles, it was better able to provide support for the new shoots that quickly sprouted and grew from several points along the stem. The development of a substantial root mass added to the stability. The okra plant grew into an exceptionally large, bushy and productive okra plant that did not fall over again. Incredibly, we found that the leaves transpired five gallons of water on a hot summer day. The production of okra pods was incredible.

Other material that might be used instead of pine needles include gravel, coconut husks or any recycled material that will provide some support, has a lot of air space, protects the water from sun, wind and at least limits access by mosquitoes. We have had very satisfactory results with some vegetables using cola cans placed in a pile six to nine inches deep in the pool of water.

The roots of most food plants and flowers require plenty of air to thrive. You may have heard that "more houseplants are killed by overwatering than by under-watering." The problem with overwatering is not that the roots do not like to stay moist, but that if heavily watered, water fills most of the spaces ordinarily filled by air in dry soil. Likewise, if you filled the shallow pool with heavy clay, it might remain so moist that few plants would grow for lack of air.

Hybrids of the Shallow Bed, Wick, and Shallow Pool Gardens

The Cola Can / Old Sock Garden

Our first cola can & old sock garden started out as an experiment to help people think creatively about what a plant requires to thrive. It turned out to be very successful and useful.

Take any container that has drainage holes about two inches up the sides. I normally use plastic cement-mixing trays that can be purchased at any hardware store in the USA and probably in many other countries. But the container could be any shape and made from anything as long as it has sides and no holes in the bottom, so that you can create a pool containing water and nutrients. For example, an old tire or wooden box with plastic in the bottom would work. The pool forms the reservoir for water and nutrients.

I imagine that most people have old socks that are mismatched or that have holes in them. Soft drink cans fit easily into the socks, one to three cans per sock depending on the size of the sock.

First place an empty flowerpot or other container in the center of the pool. This will be the "monitoring well." A quick glance into the empty pot will show the water level in the container. It also is a convenient place to quickly add water to the garden. Then cover the bottom with the can-filled socks, fitting them closely together. You will need to have a few socks that hold only one or two cans to fit around the monitoring well.

Give the garden an initial "charge" of fertilizer made for gardens or farms. I do this by sprinkling two tablespoonfuls of fertilizer with micronutrients and one tablespoon of dolomitic limestone across the socks. Then make a second layer of can/socks and add the same nutrients to this layer. If there is room, make a third layer. As discussed regarding earlier methods, you could try watering with manure tea as a supplemental nutrient boost, but I do not recommend relying on manure tea totally.

Add water till the pool is full. I put a tablespoon of hydroponic fertilizer in each gallon of water on the first fill. The first layer of socks soon becomes totally wet as capillary action moves water from the pool. The water then moves on to the next layer of socks etc. The end result is that the roots have abundant spaces filled with air, a constant supply of water, and a constant supply of nutrients. In subsequent watering you can just add water sometimes and water with dissolved fertilizer at other times, depending on how you perceive the plants are doing.

The roots grow in, under and through the socks and around the cans. Sometimes I cut slits in the cans with a penknife so that roots can enter the cans, but I'm not convinced that it makes much of a difference.

The photo shows cement-mixing trays with a bed of can-filled socks planted with annual flowers (impatiens).

You can now plant the garden by transplanting flowers or vegetables. Bend the cans as needed to "snuggle" the root ball into the space between the socks. Create as much contact between the root ball and the socks as you can so that water and nutrients are easily transferred into the roots and so roots can quickly start growing through the socks. Cover with a mulch of some sort to keep the sun and wind from drying out the socks. I normally use wood chips, but use whatever is convenient.

If you prefer to start the garden by planting seeds, first form a one-half to one-inch layer of potting soil or compost on top of the socks. Then plant the seeds as you would in any garden.

You could fill the socks with other materials like pinecones, gravel or even Styrofoam® (polystyrene) packing material (called "packing peanuts" in the USA). I found that the electrostatic charge that builds up on the Styrofoam® makes it difficult to fill the socks. This led me to consider making the garden from layers of cloth instead of socks. The result was an easier and perhaps even better method that I call the "lasagna garden," so-called after the famous Italian food made from alternating layers of wide noodles with hamburger made from ground beef (plus cheese and tomato sauce of course!).

A "Lasagna" Garden Made of Layers of Styrofoam® Packing Material and Old Clothing

In the United States and I'm sure in many other countries, items that are purchased through the mail often come surrounded inside the box with very light weight packing material made from Styrofoam® plastic that is shaped much like a peanut shell. They can become a disposal problem, so recycling them into a great growing medium is very attractive. (I imagine that real peanut shells might work just as well in this method, though they would eventually rot. I have never had enough peanut shells to give real peanut shells a try.)

Begin making the layered garden by selecting some container with no drainage holes in the bottom. Make your own drainage holes two or more inches up the sides. Lay a piece of cloth across the bottom and extending up one or more sides. Cloth made from man-made fibers work much better in the long term because they do not decompose. Microorganisms will attack natural fabrics such as cotton or wool, causing them to rot and disappear within one or two growing seasons. Place roughly an inch of Styrofoam® packing "peanuts" on the cloth, then lay the cloth, which you had left extending up the sides, over onto the "peanuts". It may cover all of the "peanuts" or just part of them. Now place another piece of cloth across the "peanuts" so that they are completely covered. In order to assure that all pieces of cloth are continuously wet, there should be a considerable area of contact between any piece of cloth and one or more of the other pieces. The close contact is

important because water being wicked (drawn up) from the pool at the bottom must be transferred from one piece of cloth to another until it reaches the top.

When the container is about a third full, sprinkle some regular fertilizer with micronutrients and some dolomitic limestone (dolomite) on top the cloth. If you have an organic fertilizer that you have confidence in, give that a try instead of chemical fertilizer. Add another inch or so of "peanuts" then sprinkle more of the fertilizer and dolomite. Finish filling to the top, then once again add fertilizer and dolomite.

You may now transplant directly into the bed. Move the pieces of cloth and "peanuts", cut holes in the cloth, or whatever you need to do to get the root ball into the unusual "planting mix." Be sure that there is good initial contact between the root ball and the cloth. Add some small pieces of cloth around the root ball if necessary to achieve this close contact. Place a mulch, for example wood chips, grass clippings or rice hulls, on top to keep the sun and wind from drying out the cloth and causing an accumulation of salts near the top (from salts in the irrigation water and from added nutrients).

Water the container well from the top with a solution of hydroponic (i.e. soluble) fertilizer or perhaps a manure tea. Continue until you have added enough that the water starts to drain from the holes on the side of the container. Eventually the less expensive solid garden fertilizer and dolomite will start to release nutrients, but the initial watering with soluble fertilizer ensures that the roots will encounter air, water and nutrients right from the start, wherever they are or grow into.

As the plants continue to grow, you can sometimes add water without nutrients. Just remember that when you do it will wash some of the dissolved nutrients toward the bottom of the container. As the roots pull water from the cloth the nutrients will start to move back up as capillary action pulls the water you added back to the top. But if you watered every day, or it rained every day, and the cloth never dried out, the nutrients would not get a chance to cycle back to the top. After a lot of rain, even though the reservoir may be full and the cloth is surely wet, add enough water with soluble nutrients that the roots will be sure to be surrounded with everything that they need for good growth. Ideally the container will alternate from having a full reservoir of water and nutrients to having the reservoir nearly empty.

As was the case with the sock/cola can garden, you can cover the top with perhaps an inch of good soil, compost or commercial potting mix and plant seeds directly into this. This would be the best approach if you would like to use the method but wanted to make it an organic garden.

I have found with both the sock/soda can garden and the Styrofoam® packing "peanut" garden that some annual flowers that would typically die during Florida's hot, humid subtropical rainy season may survive. Sometimes both geraniums and impatiens survived and get the autumn season off to a display of color without the usual wait of a few months for new transplants to grow. I attribute this to having starting with a growing medium that contains no insects or disease organisms and that there is a constant water supply, an enormous amount of air surrounding the roots, and the likelihood that many soil-borne disease organisms, should they find their way to the bed, do not thrive in this well-aerated environment.

Hybrids of the Shallow Bed in a Shallow Pool

Results are more reliable the closer you come to making a normal garden. Today our shallow pool gardens are basically hybrids made by placing shallow bed gardens right into the pool of water and extending least two to six inches above the maximum water level.

The roots of most food plants and flowers require plenty of air to thrive. You may have heard that "more houseplants are killed by over watering than by under watering." The problem with over watering is not that the roots do not like to stay moist, but that if heavily watered, water fills most of the spaces ordinarily filled by air in dry soil. So if you filled the shallow pool with heavy clay, it might remain so moist that few plants would grow for lack of air. (We have nothing but sand here in Florida, so have never been able to try a clay soil.)

There is an element of artistry involved in creating the medium in which the plants will grow when the bed is sitting in water. You need to create a medium with such large air spaces that no matter how much water is around, the roots will still find plenty of air, but dense enough that water in the pool can move up by capillary action and keep the medium moist. One way to achieve good aeration where commercial horticultural supplies are available is to include perlite in the growing medium. Perlite is a special inorganic material sold to make potting mixes very airy. Vermiculite, another commercial amendment for potting mixes, does not work as well because it packs closer together, but might be of some use. One formula we frequently use is called the "Cornell mix," so named because it was developed at Cornell University. The Cornell mix contains one-third perlite, one-third peat moss and one-third vermiculite. In many developing countries, perlite is too expensive to consider, but you can come up with alternatives, perhaps rice hulls.

If you have compost or any mix that has a lot of small air spaces, it may work well with most plants. A good way to create air spaces is to incorporate small particles of either organic or inorganic material. We have found that it works well to have a layer of inorganic material that will not decay placed in the pool itself. This might include materials such as sand, small gravel, small pieces of lightweight volcanic rock, or even cola cans with slits cut in the sides to allow roots to get inside. Cover this with small pieces of fresh organic matter (pieces of coconut husk, corn cobs, rice hulls, weeds, wood chips). Finally we place a layer of compost on top. In such a mix, roots will always be able to find air even right at water level.

There is one other step in the above description that will improve performance. We have found that all these large air spaces can be so effective that there may not be enough connections left to pull water by capillary action up to the top of the bed. The result is that the beds must be hand-watered from above until new plants develop roots deep enough to reach the water near the bottom. Including spaces where "columns" of compost or soil extend clear into the base of the pool can solve this problem because capillary action will then move water to the top of the garden via the columns. Newly planted beds should probably still be supplemented with hand watering until seedlings have a good start.

Why do we recommend using inorganic material in the pool itself? In our first version we did use all organic materials. The bed of pole beans did quite well—until the bottom material rotted and the level of the bed dropped. When this happened, many of the roots ended up in standing water. As discussed above, this is harmful or even fatal for the plant. With decay-resistant materials like cans or coconut husk pieces incorporated into the bed, extending well above the water level, the bed can never sink into the pool.

The Wading Pool Garden

An "appropriate technology" shallow pool garden can be made in the USA and I'm sure elsewhere too from the inexpensive plastic wading pools sold for children. I am talking about wading pools made from a single rigid piece of plastic, not the kind that is inflatable. The drainage holes would quickly destroy the latter! I recognize that this might not be affordable or available in some locations.

In areas where there has been a lot of relief work in response to natural disasters, there may be an abundance o plastic tubs/containers used to ship supplies. One could experiment with these, adjusting heights of drainage holes and depth of planting media for best results.

Make drainage holes three inches up the sides so the garden can accumulate a significant reservoir of water. Formerly we used a depth of one inch, but less frequent watering is needed with the deeper reservoir. Also tree roots managed to find the lower drainage holes and end up growing in the garden itself. The roots got in as the lawn was mowed and grass accumulated around one or more holes allowing access. At other times ants built a small mound near one of the holes allowing the roots access.

It is important to paint the wading pool for two reasons. (1) It will become brittle after a year or more in the tropical sun. Manufacturers of plastic sometimes include ultra violet light inhibitors to keep the plastic from becoming brittle, but apparently little or none of these inhibitors have been added to the plastic used in wading pools sold in the USA. (2) After a coat of paint (I chose a redwood color) you have an elegant, circular raised bed garden container ready to fill with a growing medium and plant with vegetables, herbs or flowers.

Because most kinds of paint will not stick directly on the plastic, it is necessary to first paint the pool with a "primer." You only need paint the outside, the lip and down as far inside the pool as the anticipated soil level. The parts the sun does not strike will not be harmed and also will not be visible once the pool is filled. I understand that there is now a paint that will stick directly to the pool. You can inquire about that at your paint store.

Place an empty one-gallon flowerpot on the bottom of the pool, near the center, as a "monitoring well." A quick glance inside the pot will always allows you to see the water level and judge when to add more.

What if wading pools are not for sale or are not affordable where you will be working? A ground-level shallow pool garden could be constructed with a rim of rocks, or even soil, covered with a sheet of plastic. If elevated, wooden boxes lined with plastic can be used. To keep costs to a minimum, the tire gardens constructed to retain a pool of water would seem to be the most durable and inexpensive.

The Eave Trough Garden

Visitors are struck by a variation of the hybrid shallow bed in a shallow pool that we call “an eave trough garden.” It lends itself to an easy method for making a striking wall of flowers. This technique is very appropriate any place where eave troughs are sold. Eave troughs are sold to divert water as it runs off of a roof. In Asia, similar gardens are made with bamboo. Eave troughs in the United States typically come in 10-foot lengths. I buy plastic rather than metal troughs for their lasting color and because it is easy to cut them. A 10-foot eave trough garden is very difficult to move once it is planted, so I cut them in two to make five-foot troughs. Price

First the five-foot eave trough must be turned into a shallow pool. You can make a water tight one-half to one-inch barrier” by moving a caulking gun back and forth at first one end and then the other while gently squeezing out caulking to form the “dam.” Caulking guns and tubes of caulking are widely available to fill in around a bathtub or window. Remember to allow a day for it to dry before adding planting medium. If the eave trough is made from aluminum rather than plastic you can alternatively bend the aluminum in such a way as to hold the reservoir of water. But I find that caulking is much easier.

The trough is then filled with planting medium as in the shallow pool garden. Make two “monitoring wells” instead of one by placing an empty 4-inch pot at one-third and two-thirds of the length of the trough. You will use these to add water as well as to note whether the status of the pool at the bottom. To keep the planting medium from washing out at the ends, fill two 4-inch pots and lay them on their sides at each end. Roots will easily grow into the medium in the pots but soil will not wash out.

If you would like to have an extra reserve of water in addition to what the pool at the bottom will hold, place a glass or plastic bottle upside down in the pool with the tops near the bottom. It will slowly release water just like the upside down bucket with a small hole in the lid did in the shallow pool garden.

You can now fill the eave trough with either a good planting medium (commercial potting mix, compost, etc) or use any of the materials discussed in the shallow bed garden section. I have often used wood chips for a lighter weight garden, though it needs to be watered more frequently because the chips themselves don’t hold much water. Sometimes I use wood chips or Perlite in the bottom half to ensure more air deeper in the bed and potting mix in the top half.

This technique is useful only for small plants, unless a trellis and very frequent watering are used. You can transplant or direct seed. For example, I have had good results growing leaf lettuce, onions, radishes and kohlrabi, as well as small annual flowers such as impatiens and begonias and smaller herbs. A long bed of garlic chives (also known as Chinese chives) can produce 12 months of the year for several years.

Here are specific instructions for one way I have made eave trough gardens. (Refer back to the discussion of shallow bed gardens.) After forming the water reservoir, “pool,” and placing the 4-inch pots at the end and 1/3 of the way from each end, fill the trough half way to the top with wood chips. Sprinkle two tablespoonfuls of 10/10/10 fertilizer with micronutrients and 1 tablespoon of dolomite across the chip bed and gently work them into the upper parts of the bed. Fill the eave trough to the top with compost or potting mix. Add the same fertilizer and dolomite amounts unless you know that the potting mix already has good fertility. Now plant seeds as you would in any garden.

If you plan to transplant into the trough, after adding the wood chips and nutrients, place the root ball of the plant so that the top will be near the top of the trough. It is OK if the bottom will be below the high water mark. If the root ball is so small that it will not make contact with water, remove wood chips under it to below the high water mark and fill the hole with your planting medium to help wick water up to the rest of the plant.

URBAN AGRICULTURE RESOURCES

Cities Feeding People: An Examination Of Urban Agriculture In East Africa (146 pp.) argues the case that urban food production should have a larger role in providing food for city dwellers. The book, published by International Development Research Centre (IDRC) in Canada, documents the extensive role of urban agriculture practiced in East Africa, with detailed case studies from Tanzania, Uganda, Kenya, and Ethiopia. The study is insightful for people seeking to understand and promote food production in the cities. It is on IDRC's website (http://www.idrc.ca/upe/ev-9354-201-1-DO_TOPIC.html). In the left side of IRDC's home page (http://www.idrc.ca/upe/ev-1-201-1-DO_TOPIC.html) click on the "publications" link to find other publications.

RUAF Foundation (http://www.ruaf.org/)

This website contains a wealth of information on urban gardens in developing countries. There are links to a number of papers, books and a host of other organizations.

ECHO Website (http://www.echonet.org/content/urbanGardening)

The ECHO website contains further in-depth information on urban, rooftop and community gardening. This includes an online powerpoint presentation and fact sheets on crops that can be grown.

All photos taken by Dr. Martin Price, unless otherwise noted.