EDN ISSUE 30 -- A SPECIAL EXPANDED ISSUE ON ROOFTOP GARDENING

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PART I. THE POTENTIAL OF ROOFTOP GARDENING

INTRODUCTION TO OUR SPECIAL EXPANDED ISSUE. One of ECHO's purposes is to help people grow food under difficult conditions. You are not likely to encounter a soil worse for gardening than a cement slab. Neither will you find such large areas of unused growing space in full sun and near prime markets as on cement rooftops in Third World cities.

The most expensive agricultural land is always that located near large markets. If there were large areas of unused flat land right in the middle of huge population centers, the potential value for producing vegetables would be obvious. How many acres of unused flat rooftops do you suppose there are in the cities in your country?

For the past eight years ECHO has been working on methods for gardening on rooftops. It turns out that cement slabs are not nearly as difficult a challenge for gardening as one might think. In fact, they have become one of my favorite gardening spots. They offer an enormous and almost untapped opportunity for ministry to urban populations. (There are also applications in certain rural settings as well).

Many church-related groups are looking for practical ways to help the people they minister to spiritually. There do not seem to be many options (medical help, community organization, and development of small businesses seem to be the major areas). Urban gardening has a reputation of not being very successful overall. I think the rooftop gardening methods outlined in this issue of EDN will not be limited by some of the factors that have caused other urban gardening projects to fail.

This issue of EDN is being devoted to the subject of rooftop gardening. Its purpose is to (1) help you evaluate its potential for your area, (2) give sufficient technical details to get started, and (3) set up an informal network among those of you who decide to try rooftop gardening so we can learn from each other's experience. Even if you never use the technique, I think this discussion will give you a new understanding of how plants grow and of their adaptability to different conditions.

I will use the abbreviation RTG for rooftop gardens.

SOME CRITERIA FOR ROOFTOP GARDENS. (1) They must not be made of materials imported into the country. (2) They must be inexpensive to construct, approaching no cost at all. (3) They must have a very low weight per square foot of growing area. (4) The emphasis should be on obtaining satisfactory production with minimal inputs, rather than maximum possible production with high inputs which is the usual goal of hydroponics. (5) No instruments or analyses should be needed.

A QUICK LOOK AT THREE GARDENING METHODS SUITABLE FOR ROOFTOPS.

The Shallow Bed Garden (see Figure 1) consists of a 3-6 inch bed of compost. To keep weight at a minimum, no soil is used. If a supply of compost is not available (a likely situation), fresh organic matter of many kinds can be used. Almost any vegetable can be grown in these shallow beds. Once the beds are established, their care differs from regular gardening only in the need for more frequent watering.

The Shallow Pool Garden (see Figures 5 & 6) consists of a shallow pool of water 1/8 to 1/4 inch deep formed by outlining the bed with a 1/2 inch rim of cement. Alternatively a sheet of plastic of the desired size is formed into a pool by laying sticks under each of the sides. Shallow beds are made of any material that will not tend to become water-logged (e. g. pine needles). Plants are transplanted so that the rootball just touches the top of the water. A 3/8 inch hole is drilled into the tightly fitting lid of a 5 gallon plastic bucket, about 1 inch from the edge of the lid. The bucket is filled with water containing a complete hydroponic fertilizer and placed upside down in a clear spot in the "pool." A stick is placed 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 exact depth depending upon how much the stick raises the edge of the bucket.

The Wick Garden (see Figure 7) consists of a piece of polyester cloth laid out on the rooftop in the shape of the desired garden. The root balls of transplants are set directly on the wick. [The term "root ball" refers to the roots and soil that is attached to them when a plant is removed from the container in which it has been growing.] The beds are finished by filling in around the plants to a depth of at least 6 inches with any material that will not tend to become waterlogged, but leaving a section of the cloth clear to hold the upside down bucket. The wicking action of the cloth keeps water and nutrients spread out and available to the plants.

OTHER USES OF ROOFTOP GARDENING TECHNIQUES.

Protection from animals and floods. Melissa McDonald tells me that on the island where she is working, Ihla Combu, along the Amazon in Brazil, all gardening is done in shallow beds on platforms. During part of the year the entire island is under water and houses must be built on stilts. Wayne Smith reports that people in another part of the Marina in another part of the Amazon plant gardens on platforms to avoid damage by animals. "They make a platform of stucks, an old canoe etc. from 4-7 feet tall, 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.

Wheel chair gardens for the handicapped. Platforms with shallow beds make gardening available to people with physical handicaps that prevent them from working in the soil. If placed at the right height, people in wheel chairs can garden easily.

Avoidance of soil diseases and pests. Root knot nematodes are such a problem in our soils here in Florida that susceptible plants cannot be grown unless the soil is sterilized. However, some fungi that live on decaying organic material 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 a shallow bed garden) or no soil (as in the shallow pool or wick gardens) we have NO root knot nematodes. (After a couple growing seasons, 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.)

Here is another application of our RTG work to "dirt farmers." One season I planted a few rows of green beans in the soil and, right beside them, a few more rows in a shallow bed garden. This bed was made of grass clippings just as though it were on a cement slab, except it was in direct contact with the soil. Roots of beans from the grass clippings were totally nematode free; roots in the soil were covered with knots. Often at ECHO nematodes kill sugar snap peas before they bear, except when planted in a shallow bed of grass clippings on top of the soil.

Ability to garden in the shade of trees. RTG techniques can be used to make beds on a sheet of plastic under trees. Tree roots are not damaged by tillage; the plastic prevents them from interfering with the vegetables; and many plants benefit from light shade.

IS ROOFTOP GARDENING JUST ANOTHER "FAR OUT" IDEA? We have asked ourselves that question many times, because the world is full of appropriate technology "answers" that never take off. It is not difficult to list possible problems. The poor may live in homes with rooftops that cannot even bear the weight of a person. Those with the most substantial rooftops may have the least incentive to garden on them. Fertilizers may not be available, especially those with micronutrients. People may not be prepared to give daily care to a garden. Water may be scarce and have to be purchased. 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. You may recall the Peace Corps advertizement that showed a glass with some water in it. The voice said, "If you see this half-empty glass and think it is half full, the Peace Corps wants you." That is the attitude that will be necessary to see successful RTG 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 special effort. Let's begin with those thousands of situations where the above problems are not limiting -- while we consider how to include more people.

What Would a Success Story Look Like? I could easily imagine someday writing a report like the following.

The pilot project is in one of the sprawling new settlements that have grown up in the hills around the capital city. It is supported by a $140,000 United Nations grant to demonstrate how a simple low-cost technology can help relieve poverty by utilizing the only asset most poor urban families possess -- their house.

Using his rooftop ... Mr. Lopez has raised the family income by 15% and estimates that their diet has improved 30%. "A lot of people think that because hydroponics is sophisticated, it is also expensive," says Paolo Castrillon, director of the project. "In fact it is very cheap if you use local or recycled materials." The project uses donated rubbish -- rice bran from a mill and wooden crates from an auto parts shop -- and recycled polythene from commercial flower farms which costs only 25 cents a kilo compared with $3.50 for new material.

The materials required are a seed bed covered with a sheet of black polythene, topped with a thin layer of soil and a porous substance such as sand, charcoal or bran. This anchors the plant roots, allows oxygen to pass through and helps retain moisture. The seed bed is given a daily sprinkle with a solution containing all the trace elements required for growth. ... It costs families less than $5 to set up one square meter plot and under $9 per year to operate it.

In addition to what the families eat themselves, the cooperative sells over three tons of vegetables each month.

Water is scarce: women have 20 minutes every other day to snatch their household ration from the communal tap. Here and there, rich green foliage decorates a terrace, a rooftop, a small backyard. "We'd never have thought you could grow things without earth. It's leaving us a profit too [$15-18] every now and then. And that's if you only have 10 square meters like me."

More than 130 families are involved. The plants grow in a mixture of rice husks and coal slag about 8 cm deep. Although the solution containing about 15 minerals is bought commercially, it represents less than 7% of the cost of production.

The urban farmers are nearly all women. Those with small children can stay at home and earn some money, instead of spending a large chunk of their wages on bus fares to jobs on the other side of the city. By the second harvest -- lettuces are sold after 80 days -- the investment has already been paid off.

A supermarket chain has agreed to take produce from the community and has even suggested growing some exotic varieties. Some women are now specializing in selling seedlings. Hydroponic cultivation has crept into the local school curriculum. Las Gaviotas has rented a large room where supplies are kept and vegetables collected. Once a week produce is brought in, weighed, and paid for on the spot. From the sale of vegetables grown on the center's roof, it will be possible to pay the rent.

Now for a confession. **THE ABOVE ARE ALL TAKEN FROM AN ACTUAL PROJECT!**. Two articles were brought to my attention just as I was preparing to write this issue (Earthwatch No. 37, 1989 and an article that appears to be a United Nations publication). It turns out that a Colombian organization, las Gaviotas, has independently developed a shallow bed, hydroponic system with many similarities to what we have discussed. I am trying to get in touch with them. (Do any Bogota readers know them?)

PART II. TECHNICAL DETAILS

HOW TO MAKE A ROOFTOP GARDEN -- THE SHALLOW BED GARDEN. (See Figures 1-4I believe that shallow bed gardening will be the method most readers will chose. It has the most in common with ordinary gardening techniques, is the simplest, and usually the most reliable.

If you have enough compost to make a 3 inch bed, this technique is very straightforward and most of the following discussion would not be needed. If you find the following a bit complex, and wish for more precise directions for amounts, times etc., remember two things. (1) Much of our discussion deals with how to start a garden in fresh organic material if you do not have compost. (2) The inexpensive raw materials available for making the garden differ from place to place, and the techniques used vary depending upon what materials are used.

In the following discussion I share enough information that you will be able to do your own trials for a season or two and do some problem solving. 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 gardeners in your community.

Shape of the Shallow Bed Garden. 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.

Our first model garden consisted of a three foot deep bed of wood chips. (Wood chips are much lighter than soil.) We got the idea from local nurseries. They sell to apartment dwellers half bushel bean hampers filled with wood chips and each containing a single tomato plant to be grown on their balcony. Gardeners are instructed to pour water containing a soluble fertilizer over the plant each day. The hampers work well and the taste of the tomatoes is exceptional.

Our deep garden used large amounts of fertilizer. A very important point to remember in working with organic matter that has not yet decomposed is that the microorganisms that cause organic matter to decay use the same fertilizer elements as do plants. This becomes a special problem if, as is the case with wood chips, the material itself is low in nutrients. The decay process can use up the nutrients, leaving the plants anemic. (These nutrients are not permanently lost. They will become available months later when the bed has been transformed into compost.) Some plants thrived, others always showed nutrient deficiencies.

After several trials, we discovered that beds only 3 inches deep were not only lighter in weight but gave better results. After several years of growing in shallow beds, I would now describe the ideal RTG as being at least 3 feet wide and only a few inches deep.

The ability of vegetables to grow in shallow beds should not have surprised us. Greenhouse tomatoes, lettuce and cucumbers are often grown hydroponically in long rectangular bags 6-12 inches wide and a couple inches high that are filled with planting mix. Plants thrive even with such a small root volume because just the right amount of water containing a soluble fertilizer is continually dripped into the medium.

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.

The question of weight. We have placed great emphasis on developing very light-weight beds. Hence we usually chose a depth of only 3 inches and use no soil.

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) 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, 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. Table I compares the weight of a 3 and an 8 inch deep bed that is 4 feet wide and 8 feet long (7.6 x 122 x 244 cm), one with soil and one with well decomposed organic matter, both fully saturated with water.

TABLE I. MAXIMUM WEIGHTS OF FOUR RTG'S.

DEPTH	WEIGHT	
	well decomposed organic matter	good 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)

If cement block sides were used, the weight would be considerably greater. Based on what I have seen in Haiti, we have been more cautious than necessary. As you can see in the pictures, they use concrete blocks for sides (we use no sides) and depths equal to the 8 inches of the blocks. No problems have been reported although I saw perhaps half a dozen gardens. If there is any doubt about safety, remember to put the heaviest items (like a barrel of water) directly over walls.

(For less sturdy structures where weight is a serious consideration, the weight of the wick and shallow pool gardens can be almost insignificant. They can be placed on the outer edge of the rooftop so that people will not need to walk on the roof.)

Materials for the Shallow Bed Garden. No material will serve better for making a shallow bed than fresh compost -- if you have it. Because compost is always in short supply, we need to consider alternatives.

If compost is not available, I use some mix of undecayed organic matter. The choice depends mostly on what is being thrown away in your area. We have used wood chips because they are free from the electric company after they trim along the electric lines. Our favorite material is grass clippings. Contractors who mow lawns for homeowners would much rather give ECHO their load of grass clippings than pay the county landfill to take them. Barbara Daniels in California, who developed a similar method of RTG independently, prefers a mixture of tree leaves. Perhaps the best results may come from a mixture of materials, which can include weeds.

Waste materials in the Third World will likely be different but equally useful. Perhaps bagasse (i. e. sugar cane waste), rice hulls, coconut husks, weeds, leaves or even manure are available in your community. We just started a trial with charcoal in Haiti. (Sawdust is available in places, but would be my last choice. It will use up fertilizer even faster than wood chips and can easily become waterlogged). No matter what organic material you use, after one or two growing seasons it will have decomposed into a beautiful compost.

The beds do not need to contain organic matter as long as the material is fine enough to hold sufficient water. For example, gravel has been used in various hydroponic systems for years. Non-organic media have an initial advantage in that the lack of decomposition means that only the plants, not the decaying bed, are using up your fertilizer, but in the long run non-organic beds are more fickle. A sudden imbalance in nutrients or swing in pH (acidity or alkalinity) can more easily develop. Organic matter, even if only partially decayed, acts as a buffer to prevent extremes. This happens because after a few weeks nutrients begin to be released from the decaying material. If the plants need more of a particular nutrient than your solution is supplying, the bed itself provides a certain amount of it. Conversely, organic material is able to absorb, for later release, some of the excess nutrient you might add. It also resists changes in pH.

Experiment with mixtures. When possible, if compost is not available, we like to use a mixture of materials. Mixtures are especially good because you have more flexibility to create the kind of environment that roots like. It also lets you use common garbage items. One of our more interesting beds is made of approximately 60% by volume crushed cola cans. The other 40% is the remains of a grass clipping bed, now turned to compost, mixed between and placed on top of the cans. Added advantages are that it provides good aeration and a deep bed with exceptionally low weight.

A 2-5 inch layer of weeds packed closely together on the bottom and covered with perhaps a couple inches of grass clippings or (better) compost from a previous bed works well. The 6-8 inch deep bed for corn (Figure 2) 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.

Constructing the Shallow Bed. 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 a mulch is placed on top of the bed. We only use sides for platform gardens or where appearance is important. We have had a lot of heavy rains and strong winds over the years. The only bed that gave us erosion problems was one in which we used a large amount of silt from the bottom of a fish pond.

The shape of a shallow bed is determined by the same considerations that one uses in making a raised bed. 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) that a person can reach to the middle of the bed. 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 is probably the most efficient.

If a sheet of plastic is available, we like to use it for a base. Experience may later show this is unnecessary, but we believe it may minimize discoloration of the roof and slow any possible seepage into cracks that might exist. No doubt it will always be wet under the plastic, but that is less of a worry than a considerable supply of water in direct contact with the roof.

Let us use grass clippings as an example. We leave the grass clippings in large piles until needed. It is best to let them decompose in a pile for at least a few weeks because the high temperatures in the piles allow much of the composting process to take place there rather than in our garden. Also we believe (no data) that most pesticides that might have been on or in the grass clippings are destroyed during this time as well.

If the pile of grass clippings is not too old, the contents will be fluffy and moldy. (Be careful breathing the dust. I have developed quite an allergy to it, though none of my staff are affected). Start with a pile high enough to allow for shrinkage during the initial preparation and continuing as the bed decays.

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 deep may be dry. When this happens, add a couple tablespoons full of 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. While adding water, if the clippings are fluffy, walk over the bed and stomp down the grass as much as possible. If the bed is made of other materials that do not need to be compressed, such as wood chips, rice hulls, or dense clumps of grass clippings that have spent several months in a pile, the materials are simply placed in the bed, wet down with detergent solution, and fertilized.

WHENEVER POSSIBLE cover the new bed with an inch or more of compost before fertilizing and planting. Remember that compost is the ideal medium. We are using these other materials only because we lack enough compost.

Finally we add an ordinary garden fertilizer and dolomitic limestone. If it is 10/10/10 fertilizer, we add 5 pounds per 100 square feet. (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 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, the micronutrients that will soon be released by the decaying organic material <u>may</u> be sufficient. One can often buy micronutrient formulations separately. 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. (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 for a couple weeks.)

If you cannot find dolomitic limestone (dolomite), I doubt if it will matter too much as long as some of the organic matter has begun to decay. Go ahead and add regular limestone instead. The main function of the dolomite is not to control acidity (this has never been a problem for us) but as a source of the two minor nutrients: calcium and magnesium. (Ordinary limestone adds calcium, dolomite adds both calcium and magnesium). A commonly available alternative source for concentrated magnesium is epsom salts.

Whether you use fertilizer or manure and manure tea depends on your location (and philosophy). In many urban situations it is easier to obtain fertilizer than manure. You can develop very precise instructions for a system designed to use a particular commercial fertilizer. The response of plants to manure depends upon the age of the manure, the animals' diet, and on the kind of animal. (Goat manure is reportedly one of the best manures for hydroponic systems. This may be because goats are browsers, eating a little from many kinds of plants each day. Consequently their manure has a composite of nutrients found in a wide variety of plants).

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. If you cannot cover the entire bed, 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.

Transplanting likewise can demand special care if the medium is not similar in texture to soil. We often 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 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 best woodchip gardens were grown by watering 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.

Refurbishing the Shallow Bed -- 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 a beautiful compost is formed. Because there is no soil in the beds, the material turns deep black and may eventually look 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. 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, all that may be necessary is to apply fertilizer. The bed should not need as much as when it was new. Much of the bed, depending on its original composition, has now been converted to compost. 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. WATCH YOUR PLANTS FOR CLUES AS TO WHAT THEY MAY NEED.

The task of refurbishing is much easier than making 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 desired material onto the empty bed, then place the remains of the old bed back on top of the new material. We add some fertilizer (perhaps a bit 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.

What plants will grow in a shallow bed? We have had success with a wide variety of vegetables: amaranth, broccoli, cabbage, cow peas, corn, eggplant, cucumber, green beans, herbs (rosemary, tarragon, basil, sage, mints, chives), kale, kohlrabi, lettuce, okra, onions, quail grass, radishes, sugar snap peas, tomatoes, winged beans and a variety of flowers. It is easier to say what crops may give problems. We stay away from large vines, such as tropical pumpkins, jicama or sweet potatoes, that have such a large leaf area that they would quickly deplete the reserve of water in the shallow bed. However, with sufficient volume (either a deeper bed or fewer plants in a bed) or more frequent watering, there should be no problem growing vines such as pumpkin or watermelon, letting them flow over the side of the building.

Root crops require deeper beds. We have grown acceptable carrots in grass clippings, but had to make the bed about 8 inches deep. It shrank so much during the growing season that the carrots stuck out of the top by at least an inch. One time we got L-shaped carrots because we planted them in a bed that was too shallow. Carrots grown in wood chip beds were distorted because of the twists and turns the tap root had to make to avoid wood chips.

NON-RECIRCULATING HYDROPONICS. (See Figures 12-14). A few years ago Hideo Imai at the Asian Vegetable Research and Development Center in Taiwan sent us a description of a non-recirculating hydroponics system he had developed (an abbreviated version was since published in HortScience, vol 23, 906-907 (1988)).

People often get excited about hydroponics for Third World situations. I have never been among them. Hydroponic systems tend to be expensive, require energy and equipment for circulation of the water to get oxygen and nutrients to the roots, and demand close monitoring of nutrient concentrations. Its value is in situations where expense of production and price of product are very high, e. g. growing winter greenhouse tomatoes near a large northern city. The 3-4 fold yield increases from high technology hydroponics may pay in such situations. I am unaware of many Third World situations in that category, especially which would involve peasant farmers. Also, if a pump breaks down where parts are unavailable or the power goes off, the entire planting can be lost. Dr. Imai's system gets around this to a considerable degree. The following discussion is abstracted from his reports.

Plant roots require oxygen, but I had not realized until Dr. Imai's paper that not all roots require the same amount of oxygen. Plants can form what he calls oxygen (O) roots and water/nutrient (W/N) roots. Roots exposed to air become short and stubby and specialize in taking up oxygen; those immersed in water become long and thin and specialize in taking up water and nutrients.

Figure 12 shows a schematic of a smaller adaptation of Dr. Imai's system. In the commercial unit, plants are suspended in holes cut in a lid that covers a 0.5 meter deep trough. The roots extend through the air, spread out onto a net, and then pass into water a few centimeters below the net. The purpose of the net is to provide support for extra O roots, which spread out over the screen. A smaller number of W/N roots drop on down into the water, but no further than 15 cm due to the limited amount of dissolved oxygen.

When the water level drops, the W/N roots change into O roots, a process taking only 2-4 days. However, this is not reversible. If solution is returned to the original depth the plants wilt within a few hours and do not recover. I can confirm this personally. When my interns left for the holidays it fell to me to maintain our first unit. I was surprised at how many gallons it took to get the water back to where I mistakenly thought it had been maintained. Water now covered roots that had been transformed into air roots. By the next evening the plants looked almost like they had been through a frost, and did not recover.

ECHO did some interesting trials with the non-recirculating concept at the Caribbean Marine Research Center in the Bahamas. We thought it had potential for islands with only rock for soil. They had an unused commercial hydroponic unit in a greenhouse. We disconnected the pumps and grew very acceptable tomatoes, cucumbers and peppers with non-recirculating nutrient solution in each trough.

In the Bahamas shade cloth covered the plants. This lowered temperatures both the leaves and the solution in the troughs compared to the trials at ECHO where we did not use shade cloth and production was lower. Without shade cloth the plants must take up more water and problems develop more readily. At high temperatures there is much less oxygen in the water too. (Funding problems interrupted the trials in the Bahamas. If you are interested in developing the concept further we can send technical details. Request the report on our work in the Bahamas and Dr. Imai's article. (Unless you work with Third World community development, enclose $4 for photocopying and postage.)

I am not recommending this system for RTG's. After many trials we consider it too expensive, too heavy for a RTG, a breeding ground for mosquitoes, and too temperamental for mass use. However, we learned from it some important things about how plants grow. It also influenced development of the other two systems which we do recommend.

SHALLOW POOL GARDENS. (Figures 5, 6, 11, 15). Pat and Connie Lahr were, until last fall, missionaries in Port-au-Prince, Haiti, working on urban gardening. Much of their work was done on rooftops, both because of the available space and because RTG's do not require fences to keep out animals or strangers. Pat believed the daily watering that shallow bed gardens required would be difficult to ensure. Like us, he thought the non-recirculating hydroponics was still too elaborate and expensive. He came up with a fascinating hybrid of the two.

Most of the materials needed for the non-recirculating system are to make the large water-tight trough and to provide a means to suspend the plants over the water. His shallow pool garden avoids both. If the roof is flat and free of cracks, he mixes cement and forms a 1/2 inch lip around the outer edges of the proposed bed. When filled with nutrient solution this then becomes a shallow pool. An alternative way to form the pool is to use a plastic sheet, raising each edge 1/4 inch by placing sticks or pebbles under it (see page 1).

Seedlings are started in "root trainers", the 4 inch deep plastic "six packs" that are commonly used in reforestation projects. Pat had a ready supply of pine needles, so these were placed over the pool to make a deep (about 8 inch), fluffy bed. The seedlings are transplanted into the pine needles so that the tip of the root ball just touches the top of the nutrient solution. (A good way to get seedlings started is to stand the root trainers, tightly together, is a shallow pool covered with both shade cloth and a plastic sheet.)

The purposes of the pine needles are to (1) provide some support, (2) ensure that only the tip of the root ball is under water, (3) ensure high humidity in the lower couple inches so that air roots can grow, and (4) keep sun and rain off the root ball and air roots. <u>Do not skimp on material for the bed</u>. Pine needles are so airy that they can and should be piled well above the top of the root ball. When we used more shallow layers of pine needles, larger plants like egg plant grew but tended to produce little fruit.

We have found it is important to give the plant plenty of room to develop air roots by creating a tall root ball. Transplants from 4 inch deep six packs do better than those from the usual 1 inch deep six packs. (If not very careful, half of the 1 inch root ball will be immersed in water). Another way to create more air roots is to plant into simple containers. These can be something like milk cartons with the bottoms cut out and with slits in the sides, rings formed from torn-apart cross sections of banana stems and arranged into a rough circle, or even just a pile of compost.

Containers within the beds help greatly when it is desired to plant seeds directly rather than transplanting. We have had good results by making long narrow rectangular bamboo planting containers within the beds (air roots can grow out between the pieces of bamboo). The containers have no bottoms. The space between the containers is filled with a deep layer of pine needles. The depth of the bed must be sufficient to ensure that the lower couple inches above the water are maintained at the high humidity required for development of air roots.

To increase the length of time needed between waterings, Pat used a principle that farmers have used for decades to automatically water animals. A 3/8 inch hole is drilled in the lid (one inch in from the edge) of a 5 gallon bucket (Figures 5 & 6). The bucket, filled with nutrient solution (water containing a complete hydroponic fertilizer), is placed upside down in the pool. The side of the lid nearest the hole is raised to the desired solution height by resting it on a stick. Water flows from the bucket until air can no longer get under the lid. This ensures a continual, shallow pool of water and nutrients for the roots. When the pool level drops enough to allow a few bubbles of air into the bucket, more water flows into the pool.

Taller plants will likely fall over. Do not try to stand them back up as you may break roots and it is not necessary. In our first trial with the system, an okra plant in a 4 ft square shallow pool garden fell over when it was a couple feet tall. Shoots grew rapidly from several points along the stem. These new shoots, supported by the portion of stem on the ground and the now substantially larger root mass, did not fall over and grew into an exceptionally large, bushy and productive okra plant. We found that the leaves transpired 5 gallons of water on a hot day.

A variation of this technique that might be useful for wall gardening is to use a gutter spout to form the shallow pool. (See Figure 14). Bend the ends of a gutter spout so it holds about 1/2 inch of water, then fill with medium as in the shallow pool garden. Because there is no bucket, you will need to add nutrient solution at least twice daily. This technique is useful only for small plants. Leaf lettuce and kohlrabi do quite well.

WICK GARDENS. (Figure 7) Similar principles are involved in another innovation of the Lahr's. Pieces of polyester cloth are laid out to the dimensions of the desired bed. Seedlings are transplanted into a deep bed of an airy material such as pine needles, as was done in the shallow pool system. The bottom of each root ball must touch the cloth. The 5 gallon bucket is placed upside down (no stick to raise one side of the bucket this time) on a piece of cloth extending from the side of the garden. I'm not sure how air gets into the bucket. Apparently a seal develops between the lid and cloth and the space between them is filled with solution which "wicks" out and keeps the entire cloth-covered area drenched in nutrient solution.

Polyester cloth is chosen rather than a natural fabric because it is slower to decompose. Cloth made of natural materials such as wool or cotton are composed of building blocks common to many living organisms (amino acids or glucose respectively) and are readily attacked by a variety of microorganisms.

The cloth moves water within your bed as surely as a pipe might carry water to a garden. Just as you would chose a pipe that was large enough for the job, you should use the thickest cloth you can find. A very thin cloth that we used failed to transport enough water. Alternatively you can use more than one layer of cloth. After harvest you will find that there are two thin mats of roots, one covering the top surface of the cloth and one between the cloth and the cement.

The portion of rooftop used for a wick garden must be very nearly flat. If the slope is great enough to cause water to flow, it will continue flowing right off the edge of the cloth. If the slope is just a little too steep for either the wick or shallow pool techniques, we have had success by using a combination of the two. We made a cement rim along the lower edges of the garden only, then covered the entire area to be gardened with a cloth. Where the pool stops the water continues up grade to the rest of the garden because of wicking action. The bucket must be positioned at some point lower than the top edge of the rim, or the pool will overflow.

You have heard it said, "There is nothing new under the sun." I recently noticed capillary mats for sale in a greenhouse supply catalog. Commercial growers of bedding plants place the mat on a flat surface, keep it moistened with nutrient solution, and place pots with cuttings or seeds directly on the mat. (By the way, we purchased some of the material and compared it to polyester cloth. We notice no difference).

COMPARISON OF THE THREE RTG TECHNIQUES.

Shallow Pool and Wick Methods. It is difficult to imagine a garden that is lighter in weight than a wick garden. The shallow pool is a close second. This is not an advantage on most cement rooftops, which can easily accommodate several shallow bed gardens (which are themselves less heavy than container gardens filled with soil). On less sturdy rooftops, however, the difference could be important.

When a shallow bed garden has been newly constructed out of undecayed organic matter, it is sometimes tricky to add just the right amount of fertilizer to provide for the needs of both the plants and the microorganisms that are turning the bed into compost. This is not a problem with the shallow pool and wick systems (the rate of decay of the fluffy pile of pine needles is not rapid enough to be much of a factor).

The most serious disadvantage is that the shallow pool and wick methods are almost strictly hydroponic systems. As such, very complete hydroponic fertilizers must be used. This means that not only must the major nutrients (nitrogen, phosphorous and potassium) be supplied in the nutrient solution, but the two minor nutrients (calcium and magnesium) and important micronutrients (iron, manganese, zinc, boron, copper and molybdnenum) as well. Other elements may be important to plants but are probably present in sufficiently high concentrations that they do not need to be added. Examples are sodium, chlorine, silicon, and cobalt.

Under circumstances found in most community development projects it is unrealistic to stock all the chemicals and mix your own, although this is technically not difficult. In many cities hydroponic fertilizer can be purchased or would become available if the market were there. A little goes a long way because, unlike field fertilizers, less inert fill is used in making soluble fertilizers. It is not unreasonable to import such fertilizers yourself as long as the project makes economic sense and a steady supply is assured.

Gardeners will fail if at any time an incomplete fertilizer is used in a system containing no or little organic matter. Let me share an example of our own. At one point we switched from a fertilizer shipped 2,000 miles by a hydroponics supply company to a fertilizer that could be purchased locally. The description led us to think it contained everything needed to maintain a soilless mix. The plants started out exceptionally well, then began wilting, leaves became discolored, roots failed to develop and many died. It turns out that the fertilizer contained every nutrient EXCEPT magnesium. The manufacturer apparently assumed that magnesium would have already been added to any soilless mix and that the fertilizer could "maintain" the mix without containing magnesium.

The volume available for air roots seems to be a limiting factor for larger plants. We did several trials of the shallow pool method with less than six inches of pine needles. Larger plants did not produce well. (Okra is an exception. It seems to be exceptionally adaptable to and forgiving of any of these systems. When we finally pulled out a single okra plant in a 4 ft square shallow pool we found a dense 1 inch thick mat of roots. See Figure 15.

The wick method does not work well during the rainy season with dense materials like grass clippings. Peppers planted near the bucket grew three times as fast as those a foot farther away. We believe it is because the dense grass clippings held a considerable amount of water after each rain and so did not put any demand on the bucket for water (hence received no nutrients.)

The bucket provides a sufficient reservoir of water that the garden might go for a bit longer than a shallow bed without attention. (This depends on the material used and thickness of the shallow bed.) However, once the pool is used up you are instantly out of water. Though a shallow bed may contain less water, the plants run out more slowly as they must extract water from the medium with increasing difficulty. In practice, I highly recommend that any of these gardens be tended daily, especially once the plants have attained some size.

Used plastic buckets can be purchased in Florida for a dollar or less from bakeries or paint stores. I believe Pat told me the price was closer to $5 in Haiti. If the price is high in relation to a day's wage, it is not only more difficult for the poor to afford, it is in danger of theft.

Shallow Bed Method. This is the most fool proof. Especially when made of compost, it differs little from gardening in the soil. The main differences are its need for daily watering and the 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.

ECHO'S WORK IN HAITI. After several years of RTG trials and demonstrations at ECHO, we were eager for an opportunity to work with the concept under actual Third World conditions. Pat and Connie Lahr's work resulted in a small network of people doing RTG before their return to the States, so Haiti seemed the place to start. The opportunity came when we began sending ECHO interns to Christianville, a mission outside of Port-au-Prince. We are helping them establish what we call a "Small Farm Resource Development Project." ECHO and its interns gain valuable hands-on experience, we help Christianville expand its agricultural program, and together can share anything we learn with the scores of other groups in Haiti.

It happens that Christianville has a large area of potential rooftop sites: staff housing, a nutrition center, a grade school, a high school, a medical clinic, an eye clinic and a dental clinic. So far we have gardens on the housing complex and are about to move onto the nutrition center. (They have enough land that the rooftops are not essential to their program. But they share our enthusiasm for using this as a base for trials and demonstrations for other groups who want to find a new way to minister in urban areas.)

We would like to be in touch with others in Haiti who have an interest in RTG. You are welcome to come to Christianville to see the gardens. An intern from ECHO might even be able to visit your site for advice or troubleshooting (if you can provide in-country transportation). The phone there is 1-40489. Alternatively, write to me so I will know of your interest and experience.

A NETWORK TO SHARE EXPERIENCES. We can learn a great deal from each other. I would like to hear from any of you who have a special interest in the subject of this issue. If you try gardening on rooftops, let us know what methods you used, what problems or successes you had, and what you have learned. Because most readers of EDN will not have a major interest in the subject, we <u>may</u> put together a special informal networking newsletter to share experiences (if enough people are interested).

NOTICE TO AID READERS. ECHO donates a few hundred copies of each issue to names supplied to us from AID in Washington (by Ed Lijewski). When you send us a change of address it will be in effect until AID sends us a completely new computerized list (every couple years). We then discard the old list. Effective with this issue, we are using a revised listing. If you change employment and wish to continue receiving EDN, be sure to request that we transfer your name to our regular mailing list.

 Subscriptions are $10 per year ($5 for students). Persons working with small farmers or urban gardeners in the Third World should request an application for a free subscription. A set of back issues since 1981 in a binder costs $20 plus postage ($2.00 USA; $6 Latin America, $9 elsewhere). ECHO is a non-profit, Christian organization that helps you to help the poor in the Third World to grow food.