Low-Tech Urban Agriculture Handbook: A practitioner's resource

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Introduction

Several of the Editors of this publication have worked in squatter settlements, slums and marginalized neighbourhoods in less developed regions of South Asia, East Africa, Central America and Canada, where residents struggle to access sufficient supplies of fresh and nutritious food. Often, many residents of these communities have conventional field-based agricultural experience and are not sure how to make use of their new constrained spaces or lands that are contaminated or not suitable for agriculture without significant modification to soil and water supplies. This handbook draws upon the Editors' experiences and the ideas of many others that have endeavoured to develop innovative approaches to low-tech urban agriculture.

This handbook aims to support the development of communities by providing ideas and step-by-step instructions for people to create their own systems of food production. The methods and tools presented in this handbook can be adapted to a broad range of geographical contexts and circumstances. It presents a sample of the growing wealth of ideas to establish low-tech urban agriculture solutions, and includes topics on irrigation, composting, creative horticulture methods, and the utilization of vertical space.to create local supplies of fresh and nutritious food.

The information in this handbook has been compiled from multiple different sources that were either identified as 'free use' or permission was obtained from the original authors and publishers. This information has been organized for ease of access so anyone can easily access these innovative practices. Instructions and descriptions are presented in a way that can be easily applied and adapted to any location. Each chapter focuses on a different element of agricultural practice: irrigation, composting, creative horticultural practices, mulching and fertilizer, vertical gardening, and greenhouses. The links in the document are active so that users can quickly move to the external source that they are interested in by selecting the link with their mouse.

Have fun experimenting with the innovative methods and tools as you adapt them to your location's specific context and the range of inexpensive materials you can access.

Chapter 1: IRRIGATION

Introduction

Proper irrigation is essential, as water can be scarce or contaminated and plants simply need water to survive. Effective irrigation best practices seek to prevent water loss while ensuring that the plants get as much water as possible. Sprinkler systems or any others that spray water onto plants or deposit water on top of plants is one of the least effective ways of irrigating, and thus is not considered an irrigation best practice. Rather, irrigation best practices target the roots directly, which allow plants to absorb more water while preventing evaporation of water, ensuring that the water goes to the plants rather than being lost to the atmosphere. This way, plants get more of the water they need because they absorb water more effectively through their roots, and water is not wasted. Of course, not all best practices target the roots directly, but none will distribute water as a mist or deposit water onto the leaves of plants.

Effective irrigation practices are essential for plants to thrive. Irrigation that does not require regular hauling of water is beneficial, as it saves both time and energy. Effective irrigation practices also require that systems do not clog, and as such need to be maintained regularly and designed specifically to prevent clogging. However, some issues are unavoidable, and can only be dealt with through regular maintenance.

Irrigation Best Practices

Effective irrigation is best done by targeting the roots directly, depositing water into the soil itself. Other effective methods include irrigation that is close to the ground, below the plants' leaves. If water gets on plant leaves, it tends to evaporate and the plants will not absorb nearly as much water as they could have if they had received water closer to the roots.

Here are some effective systems for low-tech irrigation:

- plastic bottle irrigation
- PVC deep pipe irrigation
- drip irrigation systems
- self-watering bottle garden
- simple valve system for treadle pump
- buried clay pot irrigation
- waffle gardens

Plastic bottle and deep pipe irrigation systems can be quite effective, while drip irrigation can take many forms. In fact, the plastic bottle irrigation system is a form of drip irrigation, but one that targets the roots directly rather than dripping on top of the soil. Other drip irrigation systems can involve utilizing PVC pipes or other scavenged materials. Multiple different systems will be detailed on the following pages, along with instructions on how to assemble and maintain them.

Irrigation can require a lot or very little material, depending on various factors such as size of the garden and which method might work best for specific situations. The practices that require fewer materials, however, are more adaptable and universally useful. They will just require more work to set up for larger gardens.

Irrigation Details and Instructions

Plastic Bottle Irrigation

This style of irrigation is extremely simple and requires the fewest materials of all irrigation systems. The primary material needed, as the title suggests, is plastic bottles. Two-litre plastic bottles are best, but other sizes can be used as well, and may be needed for shallower soil. Additionally, larger plastic containers, such as milk jugs, can be used.

Materials needed:

- plastic bottles
- screwdriver with one-eighth inch bit or awl
- knife or scissors (optional)

There are two different ways to make a plastic bottle irrigation system. One requires that the bottle be refilled manually, while the other catches rainwater to aid with irrigation. Both systems use the approach of “deep soil irrigation”, where the water is directed deep into the soil, and transported directly to the roots of the plants.

Method 1:

1. Take a plastic bottle and poke one-eighth inch holes on all four sides at the bottle's base. Do the same about halfway up the bottle.
2. Dig a hole just large enough for the bottle beside the plant or plants to be irrigated. Insert the bottle into the hole.
3. Fill the bottle with water through the top. After the bottle has been filled, put the lid on the bottle. This helps with controlling water outflow, slowing the drip speed by increasing water pressure. If plants are not getting enough water, remove or loosen the lid to allow for faster flow.
4. If removing the lid is still not speeding flow enough to get plants enough water, make the holes slightly larger.

Figures 1a and b: Plastic bottle irrigation method 1. Photos by Josie Dyck & Cathy McCarthy, 2018.

Method 2:

1. Take a plastic bottle and turn it upside-down. Cut the bottom off to create a funnel. Alternatively, this method can also use milk jugs.
2. Ensure the lid is on the bottle. Poke four one-eighth inch holes around the outside.
3. Dig a hole beside the plant or plants to be irrigated, just large enough for the bottle to fit. Insert the bottle into the hole cap first.
4. Fill with water. This method may require filling, but will also catch rainwater and direct it to the roots

of the plants.
5. Check regularly for debris, as it will likely catch more than just rainwater.

Source: Henk, July 20, 2016, "Bottle Drip Irrigation," *Provident Living*, http://www.providentliving.org.nz/bottle-drip-irrigation/ Accessed October 10, 2016.

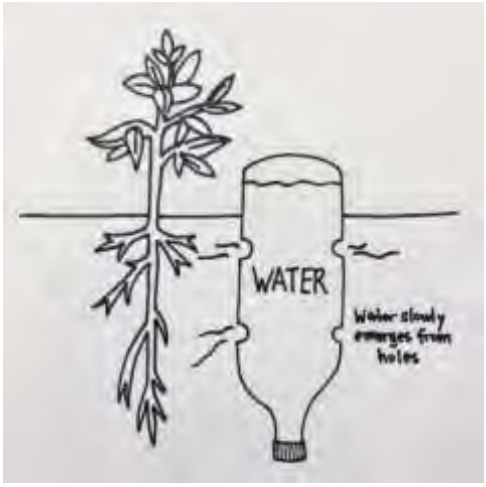

Figure 2: Plastic bottle irrigation method 2. *Illustration by Josie Dyck, 2018.*

PVC Deep Pipe Irrigation System

PVC deep pipe irrigation is best used in conjunction with container gardening, but can be useful for other forms of gardening as well. This system requires digging a hole for the pipe and inserting it so that the holes drilled in the side deposit water directly to the roots rather than simply sprinkling water on the plant.

Materials needed:

- PVC pipes
- screwdriver or drill
- saw (optional)

1. Take a piece of PVC pipe and drill holes along one side, only a few inches apart. Ensure that there will be no holes above the soil line.
2. Insert the pipe with the holes into the hole dug for it either in the container or in the small garden. Pack the soil around the pipe. A small portion of the pipe should still be visible above the soil.
3. Pour water into the pipe. The water will target the roots directly, getting the plant more water.

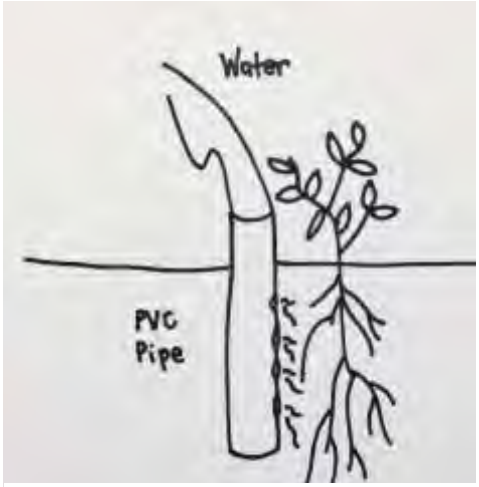

Figure 3: PVC deep pipe irrigation. Illustration by Josie Dyck, 2018

Source:
Bainbridge, David, 2014, *Get Started With More Efficient Irrigation Systems*, Permaculture Research Institute, http://permaculturenews.org/2014/04/24/get-started-efficient-irrigation-systems/ , accessed November 28, 2016.

Drip Irrigation Systems

Drip irrigation systems come in various designs, depending on available resources and space. The types of plants and their locations will determine how drip irrigation is best done. There are some ways in which to grow plants that will also not adequately benefit from deep irrigation systems, as the soil will either not be deep enough or the plant has not taken root or developed deep roots yet. Many of these systems are very useful for seedlings, which lack the deep roots needed for other irrigation

systems. Creating an effective system that delivers an adequate supply of water while preventing the plants from getting waterlogged is important.

Because drip irrigation can vary widely, here is a list of drip irrigation systems. Instructions on how to assemble each will be provided on the following pages.

Types of drip irrigation systems:

- PVC drip irrigation (multiple methods)
- rainwater drip irrigation system
- tube drip irrigation for seedlings

PVC Drip Irrigation Systems

PVC drip irrigation systems have multiple methods, each one depending on the dimensions of the PVC pipes being used, what water source is being used, and where the PVC drip irrigation system will be installed. Larger PVC pipes are useful for catching rainwater or developing drip irrigation systems higher above the ground, while smaller PVC pipes are most useful for drip irrigation along the ground. Though drip irrigation along the ground is best, some planting methods elevate plants above the ground and even install them along walls, so these systems require irrigation methods to complement this alternative planting solution.

Ground-Level PVC Drip Irrigation System

This is the most effective form of drip irrigation for ground-level gardening on a larger scale, though it can be adapted for smaller gardens as well. As the title suggests, however, this one is meant for ground-level drip irrigation only. This drip irrigation provides a slow, steady stream of water directly to the soil near the plants, which keeps the plant hydrated. This system does not water as effectively as deep irrigation systems do, so it is only recommended for plants that either have shallow roots, or the plant is just beginning to grow from a seed, or the soil is not deep enough for a deep irrigation system to be practical.

Materials needed:

- three-quarter inch PVC pipe with two end caps
- half-inch PVC pipes with one end cap each, enough for the length of the garden
  alternatively, polytubes and microtubes can be used in place of PVC pipes
- two elbow joints
- valve to control water flow
- a hacksaw
- T-connectors for PVC pipes (how many will be determined by size of area to be irrigated);
- a drill or screwdriver with a one-eighth inch bit
- bucket or barrel with material to elevate it
- two L-brackets, made of metal, rubber, or plastic
- sticks for latches

Typically, this system uses a device to begin water flow through pressure, but without the technology to do so, taking advantage of the natural environment and gravity is a suitable alternative.

1. Using the hacksaw, cut the half-inch PVC pipes to the same length. They should all be the length of the garden in need of irrigation.

2. Take the drill or screwdriver and drill holes at six-inch intervals, staggering the holes to allow for effective flow down the entire tube.
3. Lay out the half-inch PVC pipes so they go in between rows of plants. Take the three-quarter inch PVC pipe and cut pieces to fit in between each interval of the half-inch pipes.
4. Take the T-connectors and connect the three-quarter inch pipes to the wings (the two top parts of the "T" shape). Connect the half-inch pipes to the bottom parts of the T-connectors. One T-connector should be reversed and in between two of the half-inch PVC pipes, near the center of the system. This is where the barrel will connect to the system.
5. Put end caps on the far sides of the half-inch PVC pipes, and at either exposed end of the three-quarter inch PVC pipes.

How to assemble the barrel for gravity flow:

1. Cut out a section on the side of the barrel. This only needs to be large enough to allow for water to be added to the barrel. A section six inches by six inches should be large enough. Install two L-brackets at the top so the door can swing open, and two latches with sticks to hold the door closed.
2. Use materials to elevate the barrel near the T-connector that was reversed for the assembly of the ground-level irrigation system.
3. If there is already a hole in the top of the barrel, attach the valve to it. If not, cut out a hole just large enough for the valve, securing it in place with tape.
4. Attach an elbow joint to the valve and point the other end toward the ground. Attach a half-inch PVC pipe with no holes. This PVC pipe should just reach the ground. Add another elbow joint to the other end of the PVC pipe and attach another half-inch PVC pipe to it. Insert the other end of this last PVC pipe into the one exposed T-connector in the center of the irrigation system.

Figure 4: Ground level PVC drip irrigation. Photo by Weslet Vildort, 2017

Source: YourstrulybyJulie.com, "DIY – Drip Irrigation System", *The Wrinkled Dollar,* http://thewrinkleddollar.com/garden/diy-drip-irrigation-system/ - accessed December 15, 2016.

Rainwater Drip Irrigation System

The rainwater drip irrigation system works much the same as the gravity-based drip irrigation system, only with a rain barrel.

1. Take a plastic or metal barrel and remove the top.
2. Cut out a hole near the base. Insert a valve into the hole, and secure it in place with tape.

The best way to make this work is if a rain gutter system feeds into the rain barrel. Runoff from a house will channel rain water into the barrel.

Tube Drip Irrigation System for Seedlings

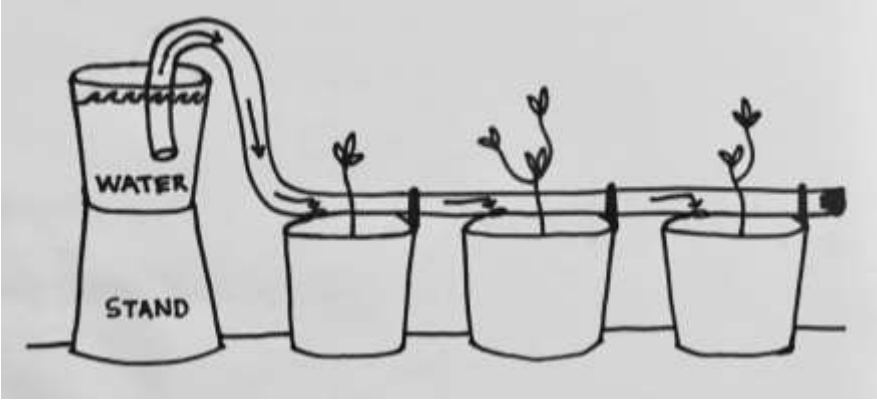

Figure 5: Tube drip irrigation. Illustration by Josie Dyck, 2018.

This one is best set up indoors as seedlings can use the protection. However, this can still be set up outside provided the seedlings have adequate protection. This is a slow-drip irrigation system that will allow seedlings to slowly grow to the point where they can be planted elsewhere and can grow to full maturity.

Materials needed:

- one strip of plastic tubing
- one small plastic cup for water, and one for every plant
- eight sticks
- string
- small knife
- needle, tack, or pin
- plastic or rubber stopper
- syringe

1. Make a stand for one of the small cups out of the sticks. Use four of the sticks as legs for the stand, and the other four sticks to hold the stand together by tying string to the sticks so the cup can be inserted into the center and is held aloft.
2. Lay the tubing out beside the cups. Poke holes in the tubing where the tubing will be in the center of the cups.
3. Cut holes just big enough for the plastic tubing into the other cups. Insert one end of the plastic tubing into the cup on the stand and thread it through the holes cut in the other cups.
4. Insert the syringe into the far end of the plastic tubing. Pull air into it to start water flow from the other side. Once water flow gets just past the bend in the tubing, remove the syringe and replace it with the stopper.
5. If plants are not getting enough water, slightly increase the size of the holes.
6. Once plants get larger, transplant them into a larger area.

Source: Andy, May 19, 2015, “Make A Drip Irrigation System – Tinker Crate Project Instructions,” *YouTube*, https://www.youtube.com/watch?v=aUUcq-DGKPQ

Self-Watering Bottle Garden

Figure 6: Self-watering bottle garden. Photo by Josie Dyck & Cathy McCarthy, 2018

This style of garden is a great way to create a small system that requires little watering. It will require refilling, but beyond that, the system feeds itself with a wick system that transfers water from a small basin to the soil and the plant's roots.

Materials needed:

- plastic bottle
- wire mesh, as for a screen door or window
- knife or scissors
- string
- soil

1. The first step is to cut the bottle closer to the top than the bottom, about one-third of the way down the bottle. Flip the top part upside-down.
2. Cut a square piece from the mesh, measuring two inches by two inches. Cut a small hole in the center in which to pass the piece of string through.
3. Pass the piece of string through the small hole in the mesh and tie a knot large enough to prevent the string from slipping through the hole. Put the piece of mesh into the top portion of the bottle, and pass the piece of string through the bottleneck.
4. Fill the bottom of the bottle about half-full with water. Put the top portion of the bottle into the bottom portion, keeping it upside-down. Make sure the string dangles down into the water. The top portion should sit on the top portion without slipping into the bottom.
5. Put soil into the top portion of the bottle. The mesh will prevent the soil from slipping through the hole, and the string will work as a wick that will carry water up into the soil. Plant vegetables or herbs in the soil.
6. Once they have grown large enough, the plants may need to be transplanted into a larger container.

Source: Booney, Grace, 2009, “We Like It Wild: Bottle Gardens”, *DesignSponge*, http://www.designsponge.com/2010/05/we-like-it-wild-bottle-gardens.html

Simple Valve System for Treadle Pump

Creating a treadle pump with minimal materials can be quite difficult. Thankfully, there is a solution using old materials to create a valve that can pump water from a bucket. This system is best used to minimize the need to carry water, which also allows for watering more quickly. A bicycle tire inner tube is used as it will kink closed when forced against its natural shape, which is what allows for this system to work.

Materials needed:

- a bicycle tire inner tube
- a flip flop
- scissors or knife
- a hacksaw
- 50mm PVC pipe (less than 1m)
- 2 T connectors
- An end cap
- 8 large metal washers
- 8 nuts
- a threaded bar
- a bit of grease

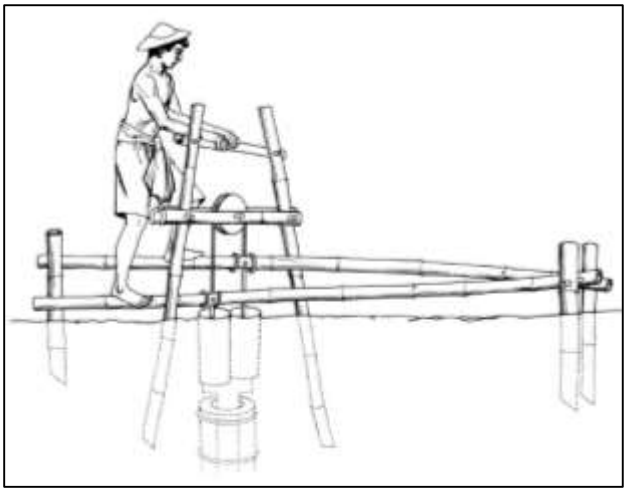

Figure 7: Treadle pump. Photo by International Rice Research Institute; Labeled for Reuse.
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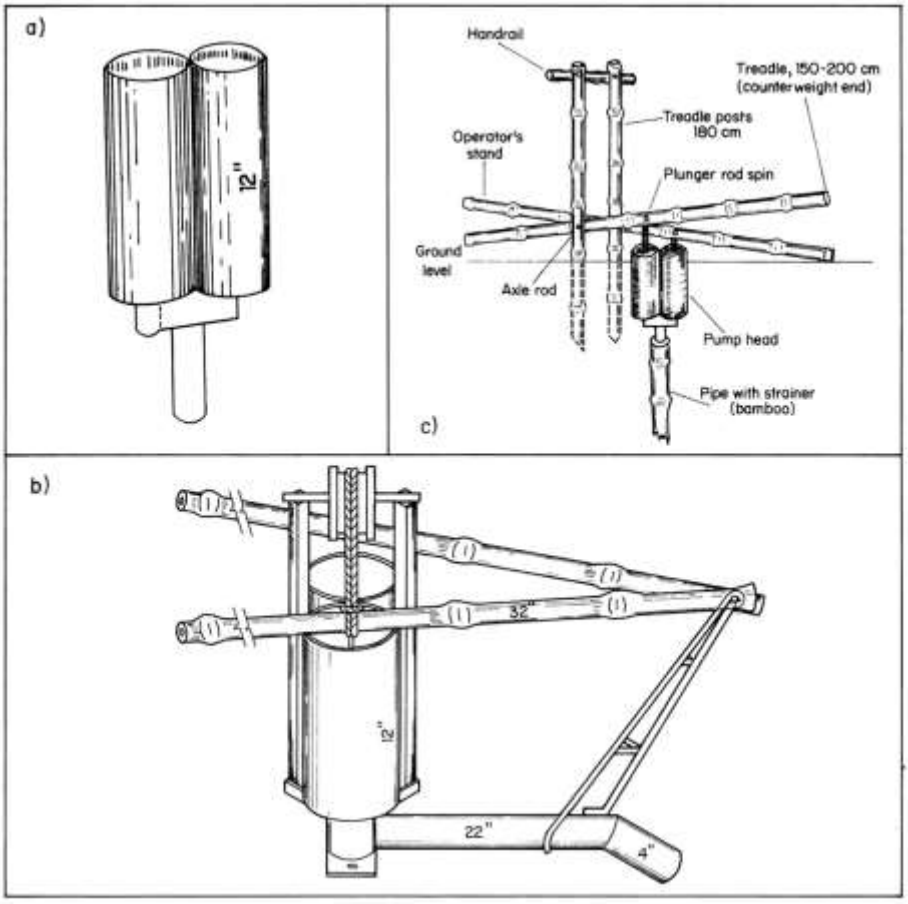

Figure 8: Treadle pump. Photo by International Rice Research Institute; Labeled for Reuse.
Phttps://www.flickr.com/photos/ricephotos/7089658469

How to make a simple valve system for a treadle pump:

1. Cut an eight to ten inch piece of the inner tube off and stretch it over the bottom of a T connector. The piece of the inner tube should bend centered along the T connector, in whatever direction is preferred.
2. Push the tube back inside itself so it folds into the larger shaft of the T connector. When pushed through, the inner tube should push in the opposite direction it was facing in step 1. This will kink this portion of the inner tube closed.
3. (optional step) Insert a threaded adapter into the T connector where the inner tube has been attached. Make sure to straighten out any wrinkles in the inner tube prior to inserting the adapter. This will hold the inner tube in place.
4. On the side that the inner tube is not pointing to, attach a short section of PVC pipe and the end cap. Set this aside for now.
5. Take a piece of 50mm PVC pipe and another T connector. Put the T on the pipe to create the pump barrel.
6. To make the plunger, first cut two 50mm circles out of the flip flop. If available, use sandpaper to round the edges so they fit snugly into the pipe. Cut holes in the center of each of the pieces of the PVC pipe just large enough to fit a piece of threaded bar through. These pieces make the plungers. The plungers will need to be secured to the threaded bar two to three inches apart. Each will need to be secured in place using a large washer and a nut on either side of each. The bottom one should be level with the bottom of the threaded bar, or at least as close as it can be.
7. Add grease to the upper side and edges of the lower plunger. Run the plunger assembly into the pipe from step 5.
8. Using anything that can be found, create a stop that will prevent the plunger from passing beyond the 50mm PVC pipe and into the T connector.
9. Make a handle at the top of the threaded bar by using another two washers and nuts.
10. Using another short piece of PVC pipe, attach the two T connectors together. This will be attached to the side of the other T connector that does not have the end cap, and has the inner tube pointing toward the opening.
11. For the outlet valve, cut another piece of inner tube to eight to ten inches. Attach it to the bottom of the second T connector and have it curving toward the end cap. The two bottoms of the T connectors should be pointing in the same direction. Place the pump in a bucket of water and bend the outlet valve against itself to lead out of the water. Have it hanging out of the bucket.
12. The first couple of strokes will likely come up dry. Keep pumping until water comes out, about three to five pumps.

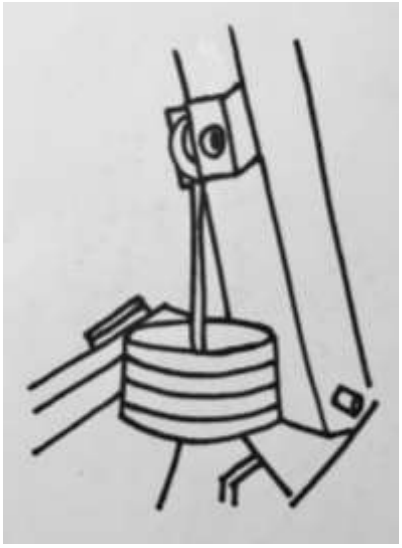

Figure 9: Treadle pump plunger. Illustration by Josie Dyck, 2018.

Source: chuang2tu, “Treadle Pump – a simpler valve solution,” *Instructables*, http://www.instructables.com/id/Treadle-Pump-a-simpler-valve-solution/, accessed December 30, 2016.

Buried Clay Pot Irrigation

Buried clay pot irrigation is simple to set up, and works in a remarkable way. Clay allows for water to slowly leach out into the soil, providing water to the roots of nearby plants. To create it, simply dig a hole and plant a clay pot in that hole. Fill with water. Cover the clay pot to prevent evaporation, and the water will slowly leach out into the soil.

Another method is to plant a smaller clay pot inside a larger clay pot. The larger clay pot should have drainage, but the smaller one should not. Water leaches out from the smaller clay pot, planted in the middle of the soil in the larger clay pot.

Source: Bainbridge, David, 2014, *Get Started With More Efficient Irrigation Systems*, Permaculture Research Institute, http://permaculturenews.org/2014/04/24/get-started-efficient-irrigation-systems/, accessed Nov. 28, 2016.

Waffle Gardens

Waffle gardens are simply ways in which to align soil to hold water in place by with the shape of the garden itself. To create it, make small compact walkways that create small barriers in square sections. These can be made out of rocks or pebbles or packed earth.

Source: Bainbridge, David, 2014, *Get Started With More Efficient Irrigation Systems*, Permaculture Research Institute, http://permaculturenews.org/2014/04/24/get-started-efficient-irrigation-systems/, accessed November 28, 2016.

Chapter 2: COMPOSTING

Introduction

Effective composting practices are necessary for the production of healthy soil. Composting done well can provide vital nutrients to the soil for healthy and efficient growth of vegetables, and if composting is done poorly, it can attract pests and cause a horrible stench. Poor composting practices may also introduce harmful bacteria to soil, preventing plants from growing effectively, and potentially poisoning and killing them. Meat and bones do not make a good contribution to compost piles, as they attract pests, introduce bacteria to the soil that is harmful to vegetables and fruits, and produce a horrible stench when they decompose. These best practices have been compiled to show that composting can be done efficiently with minimal accessible resources.

Composting Best Practices

Composting best practices that use food scraps require enclosures to prevent pests from getting into the compost and to reduce spread of the compost. Though compost can simply be thrown into a pile in a yard, it usually spreads out and decomposes more slowly as a result. Mixing of compost is essential to allow for proper airflow and to adequately distribute heat throughout the compost pile. Heat is what causes the decomposition, and without proper airflow the compost can get too hot and will cause the stench to worsen. Ideal systems will elevate compost above the ground, but others are also useful. Some do not even use food waste, and may not require an enclosure to keep pests out. Food waste mixed with other compostable materials, however, is the most effective way of creating compost with adequate nutrients for healthy soil.

Here is a list of four composting technologies:

- three-bin wire and solid enclosure compost system
- compost tumbler
- compost tumbler with a stand
- worm bins

For all of the above mentioned composting technologies, with the exception of worm bins, there are some steps that are universally necessary for the success of composting. Compost should be layered with soil or compost that has already decomposed to aid in activating the decomposition process and introducing healthy nutrients. All compost requires proper aeration, for without it decomposition would not happen at rapidly enough to cause healthy decomposition, and the stench will grow. It is also important to note that composting includes a heating process, where the interior of a compost pile heats up to facilitate decomposition. Without proper air flow, this temperature can get dangerously high. Proper turning of compost also ensures that all compost decomposes evenly. Compost also requires moisture to decompose. Water, heat and air interact with each other to facilitate the decomposition process.

Waste to Use for Compost

As previously stated, not all biodegradable materials should be used for composting. Meat and bones both create a horrible stench and can contaminate compost, introducing bacteria harmful to plants into the soil. Aside from that, other compostable materials, such as wood ash, can be useful if not treated with chemicals, and different types of wood can be beneficial depending on the types of plants to be grown (fruits thrive better with different nutrients than vegetables do).

Ideal materials to use for compost:

- fruit and vegetable waste
- plant and yard waste
- coffee grounds and tea bags
- egg shells
- wood ash, if not chemically treated

Compostable materials that should not be used:

- meat and bones;
- dairy - though potentially useful, dairy can create a horrible smell and attract pests. Milk can be used as fertilizer, but does not work well as compost;
- cat, dog, or human feces.

Source: Abbott, Catherine. *The Everything Grow Your Own Vegetables Book: Your complete guide to planting, tending, and harvesting vegetables*. Avon, MA: Adams Media, pp. 162-171: 2010.

Composting Instructions

Composting properly is essential for creating healthy, nutrient-rich soils. Different containers can be constructed to allow for adequate composting practices. Different types of composting rely on different processes to create healthy compost. It is important to note, however, that adequate moisture content, aeration, and rotation are very important to creating healthy compost for all of these methods.

Maintaining Adequate Moisture Content

Without maintaining the proper moisture content for compost, the compost either will not adequately decompose or water could leach out, creating a mess, potentially contaminating surroundings, preventing decomposition, attracting pests, and wasting water.

There is a simple method to testing compost to see if it has the right amount of moisture, and it does not require any tools. Simply take a handful of compost and squeeze gently. If a lot of moisture runs through your fingers and the compost has a muddy texture, the compost has too much water. If the ball does not stick together but falls apart into smaller clumps, there is not enough moisture. If the compost remains in a ball and leaves a bit of moisture on your hand, the moisture content is adequate.

If there is not enough moisture, add more water. If there is too much moisture, add more compost or soil and stir.

Allowing for Proper Aeration

Without proper aeration, compost will begin to develop a horrible stench. It might seem that allowing air to pass through the compost would promote the smell of compost to spread, but in fact airflow prevents a stench in the first place. The reason for this is heat management. The main reason compost develops a stench when decomposing is because it gets too hot. Heating is what causes decomposition, but if the compost gets too hot it can result in unhealthy soil. Properly managing the heat of compost is one important step to ensuring even decomposition of compost and of ensuring nutrients from the compostable materials are in the fully formed soil.

Adequate Rotation of Compost

Like adequate aeration, rotation helps to keep the heat of compost down. The reason for this is that compost piles generate heat at the center. If compost piles were never rotated, decomposition would happen very unevenly. Compost created by processes other than decomposition, such as with worm bins, do not require rotation for the purposes of heat control and distribution, but have their own unique form of rotation. In the case of worm bins, adequate rotation is necessary to make harvesting compost easier, as it helps prevent removal of the worms when harvesting by encouraging them to migrate to another area of the compost bin.

Layering Compost

For almost all composting practices listed, aside from using worm bins, layering of compost with other materials is essential. This helps with activating the composting process and introducing important nutrients into the soil as the compost decomposes. Typically, compost should be layered six inches and then six inches of fully decomposed compost or soil should be layered on top of that, repeating until the compost bin is full. Occasionally, smaller layers may need to be added. Details for those layers will be detailed in the respective best practices instructions.

Three-Bin Wire and Solid Enclosure Compost System

This is probably the most basic and most easily assembled of the compost systems. Traditional designs rely on wood for the construction of the final, solid enclosure, but other materials can be used so long as it is completely enclosed with a solid base and sides that will not cause loss of soil. This style is only useful for yard waste. Food waste with this style of compost system will attract pests.

Materials needed:

- wire mesh (the smaller the holes in the mesh pattern, the more varied the types of material that can be used)
- six half-inch PVC pipes, cut to four feet in length each
- string or fishing line

1. Dig holes for the posts for the wire mesh enclosures first creating a four foot by four foot enclosure. Dig two more holes to create a second four foot by four foot enclosure off of that.
2. Place the PVC pipes in the holes and pack them in place. The pipes should be perpendicular to the ground.
3. Wrap wire mesh around four of the PVC pipes to create a four foot by four foot enclosure. The wire mesh should reach all the way to the top. If one strip of wire mesh is not enough, wrap more around to create four foot mesh walls on all four sides. Tie the wire mesh to the PVC pipes using string or fishing line.
4. Use more wire mesh to create the second enclosure using the remaining PVC pipes. Altogether, it will look like a rectangular enclosure with a divide down the middle.

How to compost using the three-bin system:

1. Add fresh compost to one of the wire mesh enclosures.
2. Partially decomposed compost should be moved to the other wire mesh enclosure so fresh compost can be added to the first wire mesh enclosure without trapping the partially decomposed compost at the bottom, and for turning of compost.
3. Once compost from the third compost bin has been fully decomposed it is ready for use in the garden.

Source: Gilmer, Maureen, and Maureen Gilmer. *The Small Budget Gardener*. Brentwood, TN: Cool Springs Press, pp. 69-70: 2009.

Compost Tumbler

A compost tumbler is a useful tool for creating a composting system in which turning of compost is easy and efficient. Poles protruding from the sides of the compost will allow for ease of turning the compost. This style of tumbler is separate from any supports and must be rolled on the ground to tumble the compost, so it does require a bit of room.

Materials needed:

- a garbage can or plastic barrel
- two lengths of PVC pipe
- a screwdriver or something else for punching holes
- bungee cords or clips
- a knife

Figure 10: Compost bin. Photo from Wikimedia Commons; Labeled for Reuse. https://commons.wikimedia.org/wiki/File:Compost_fut_1.JPG

1. The first step is to punch holes into the sides of the tumbler. Make plenty of holes for proper aeration. Punch holes in the sides, top, and bottom of the container. Make sure the holes are small enough that compost will not fall through them, but that they are large enough to provide ample aeration; holes one inch in diameter are a good size.
2. The second step is to create the opening for adding compost. If using a garbage can or similar container, this is simple, as the lid can be removed and replaced fairly easily. If using a plastic barrel without a lid, use the knife to cut the top off.
3. The third step is to attach the pipes to the container. Two beams must be installed in the interior. These make turning the tumbler easier. The pipes need to be longer than the container. Create two holes on the bottom and on the lid of the container in such a way that allow for a beam to be inserted in one side and come straight out the other. Insert the two rods into the bottom holes.
4. The lid can now be secured, but compost must first be added. When the lid is in place, use bungee cords or clips.

Source: wikiHow, 2016, “How To Build A Composting Tumbler,” *wikiHow*, http://www.wikihow.com/Build-a-Tumbling-Composter.

Compost Tumbler with Stand

A compost tumbler with a stand is more secure, as it is elevated. This elevation provides security from pests and will also keep the container in place, so it does not require as much space. The traditional design requires a wooden base, but other materials can be used so long as they can be bound or fastened together. This design also requires slightly less assembly for the barrel itself. It does, however, require assembly of the stand.

Materials needed:

- cylindrical plastic container without a removable top

- L-brackets
- sticks for the door latch
- PVC pipes with two T-connectors and six elbow joints. Three of the pipes should be longer than the cylindrical container and the same length.
- saw, to cut down longer PVC pipes
- screwdriver for punching holes
- string (optional)
- hammer (optional)

Figure 11: Compost tumbler with stand. Photo by Angela Moore, 2017.

How to make the stand:

1. Insert half-inch PVC pipe into all three sides of each T-connector. Cut the two pipes on the sides to a length that works well for the area in which the stand will be set up. Ensure that the pipes on either side are similar in length, and that the pipes connected to one T-connector are the same length as the pipes connected to the other T-connector. The pipes running perpendicular to the two side pipes should also be the same in length on both T-connectors.
2. Place the T-connector upside-down on the ground so that the piece coming out of the bottom of the "T" shape is facing up. Attach elbow joints to the other ends of both of the pipes running along the ground. Do the same with the other side. Take two of the three longer PVC pipes and slide them into the elbow joints attached to the base to create a rectangular pattern. This will create the secure base for the stand.
3. Attach two elbow joints to the tops of the two PVC pipes pointing up. Once the tumbler has been assembled, attach the PVC pipe running through the center to the elbow joints.
4. Place the stand on level ground. If it moves too much when tumbling compost, secure it with string or other material on hand to prevent the base from sliding or lifting off the ground.

How to make the tumbler:

1. The container must be a closed cylinder/barrel with a secure top. Punch plenty of evenly spaced holes near the top and bottom of the container.
2. Only one pipe needs to go through the barrel, as the stand will hold the two ends of the pipe and the tumbler will rotate on this central pivot point. Cut a hole on the top and bottom of the container, exactly at the radius, and put the pipe through the holes.
3. Cut out a square or rectangular section of the side to create a door for inserting compost.
4. Install 2 L-brackets as hinges for this opening. These can be made of plastic or rubber material. The hinges are best added to the top of the door on the exterior of the barrel, and two latches should be installed at the bottom to hold the door closed.

The tumbler in this photo uses a garbage pail. A broom handle was used as the rotating pipe.

Source: wikiHow, 2016, "How To Build A Composting Tumbler," *wikiHow*, http://www.wikihow.com/Build-a-Tumbling-Composter

Compost Using Worm Bins

If space is limited and worms are accessible, use them to create compost. This is also an effective choice to keep smell to a minimum. It is best to use red wiggler worms, as they eat quite a bit and they reproduce quickly.

Figure 12: Worm bin composting. Photo from Wikimedia Commons; Labeled for Reuse

Materials needed:

- plastic bin with a lid or cover, 18” deep or less
- worms
- soil
- bedding material: shredded newspaper or cardboard, leaves, wood shavings, peat moss
- drill with one-eighth inch bit and one-half inch bit

Follow these steps to create a worm bin:

1. Drill 8-12 1/8” small holes into the base of the bin and 1/2” holes on the upper edge on the sides to allow for aeration. Worms require air, moisture, and food to be sustained.
2. Add bedding material. Take some paper (old newspaper works best) and tear it into thin strips. Dip it in water to create the base for the worm bin. Only dip the paper, as too much water can be just as damaging as no water. Lay this paper on the base of the bin, covering the bottom surface completely.
3. Add the worms with soil, keeping them to one side.
4. Add some compost, keeping it with the worms. Do not add dairy products, as worms tend to avoid it. Keep the compost to one side of the bin.
5. Put dry shredded newspaper over the worms to cover them, fluffing it to allow for proper aeration. When adding compost, move the dry newspaper to one side and add the new material to be composted.
6. Put the cover of the plastic bin on and put the bin in a cool place out of direct sunlight, as sunlight can quickly dry up moisture. Worms require moisture to breathe, so it is important that their habitat remain damp.
7. To make harvesting of compost without removing the worms easier, switch to adding compost to the other side of the worm bin. This will encourage the worms to migrate to the other side of the bin, as they will go where the food is. After a couple of days, harvest the compost from the first side. Alternate sides like this whenever compost is ready to be harvested.

Source: The University of Maine, 2012, “Worm Composting,” *YouTube*, https://www.youtube.com/watch?v=jJ3QIZMta98, accessed December 31, 2016.

Chapter 3: MULCHING AND FERTILIZER

Introduction

Mulching and fertilizer might seem like difficult resources with limited resources, but that is simply not the case. Much of the materials that can be used for composting can also be used for fertilizer or mulch. Mulching helps to reduce the likelihood of pests and conserve water, while fertilizer encourages plants to grow. Professional-grade mulch or fertilizer is often unneeded, and the remedies listed on the next pages actually have the potential to be more useful than other grades of fertilizer or mulch.

Effective mulching helps with weed control, resulting in less work over the long term. It also helps with water conservation and retention, as it shields the soil from direct sunlight, and can prevent erosion by protecting soil and plants from wind. It can also help with heat retention, working as a small greenhouse on the soil itself while the plants can grow past the material.

Mulching should not be done until plants have grown well past the point of being seedlings. If mulch is applied too early, the plant could be suffocated or buried. Once a plant starts to grow leaves and stands separate, then mulch can be applied.

List of Materials for Mulching and Fertilizer

Unlike the other chapters in this handbook, these best practices for mulching and fertilizer do not require long instructions for assembly or multiple materials to make them possible. This chapter is mainly focused on pointing out what materials work best and how to implement them. They will have brief instructions on how to best apply them, but beyond that all that needs to be done is to monitor the plants as they grow.

Here are a list of materials that work well as mulch or fertilizer:

- egg shells
- wood chips (if not chemically treated)
- wood ash (if not chemically treated)
- sawdust
- tree trimmings
- cover crops (also called green manure)
- pine needles
- leaves
- manure (horse, cow, or poultry)
- seaweed
- straw, hay, or leaves
- black plastic

Instructions for Effective Mulching and Fertilization

Effective mulching requires covering the soil to prevent weeds, and to promote healthy soil through decomposition of the mulch into compost. Hence, mulches should be biodegradable, though some are not and help with other aspects of healthy gardening. Mulching is meant to reduce weed content, to promote healthy plants, to protect soil from the elements, and even to prevent frost from uprooting plants as the process of water freezing causes the soil to expand.

Mulches can be a mixture of materials, or they can be a single material that can help with promoting a healthy garden. Here is a list of effective mulching techniques:

- lay plastic over the soil, ensuring not to cover the sprouting plants;
- lay straw or hay over the soil, ensuring not to cover the sprouting plants. This should be made quite thick to prevent weeds from growing through;

- lay egg shells, wood chips, or sawdust around the bases of plants. These will deter pests, such as slugs, from eating plants, as the coarse, sharp material is hard on their bodies;
- stones and pebbles also make an effective mulch. They also help to deter pests.

Figure 13: Plastic mulch. Photo from Wikimedia Commons; Labeled for Reuse.
https://commons.wikimedia.org/wiki/File:Ballyskeagh_Townland_-_geograph.org.uk_-_192973.jpg

Sources:
Burch, Monte. *The Ultimate Guide to Growing Your Own Food: Save Money, Live Better, and Enjoy Life with Food from Your Own Garden*. New York: Skyhorse Pub., pp. 60-61: 2011.
Harris, Marjorie. *Thrifty Gardening: From the Ground up*. Toronto: House of Anansi Press, 2012.

Mixing mulch with fertilizer materials is a great way to promote healthy soil while protecting it with mulch. Here are some effective mixtures:

- mix manure and leaves together with compost. Spread it early during the cold season, as compostable mulches are often best applied early during the colder months;
- when spreading wood chips, sprinkle fertilizer among them to create a mulch and fertilizer hybrid layer. The fertilizer can consist of composted horse, cow, or poultry manure; wood ash; crushed egg shells; or seaweed.

Source: Harris, Marjorie. *Thrifty Gardening: From the Ground up*. Toronto: House of Anansi Press, 2012.

Effectively applying fertilizer does not always have to be done with mulch, though applying mulch is highly recommended in gardens. Mulching in containers or other smaller spaces may not make sense, but when creating a garden plot, even with raised beds, it is definitely beneficial. Fertilizer can be useful anywhere, however, and should be applied when possible.

The best way to plant fertilizer with seedlings is to dig out a hole for the seeds and dig out two “ditches” beside the hole in which to plant fertilizer. This will allow the fertilizer to saturate the soil at the base of the plant.

Here are some tips when fertilizing:

- when using milk as fertilizer, it is recommended to use milk that is past its due date, as this helps with recycling the milk. On top of that, the milk will not be wasted as fertilizer when it could still be used as food. The best way to use milk as fertilizer is to make a half-milk half-water mixture and put it into a spray bottle and spread it on leaves and near the base of the plants as a mist.
- when using manures as fertilizer, always make sure to let the manure decompose first.
- egg shells need to be finely crushed to create a good fertilizer. This also works really well to add to compost to introduce calcium into the soil.
- seaweed is only a viable option if you live near an ocean or other large saltwater body.
- different types of wood ash adds potassium to the soil, as well as other key nutrients plants need for growth, such as nitrogen.

Figure 14: Crushed egg shells. Photo by Steve Masley, www.Grow-it-Organically.com

Sources:

Etsy, June 24, 2011, “Using egg shells in the garden,” Girl on Bike: Food, Bikes, and Sustainability, http://girlonbikewrites.blogspot.ca/2011/06/using-egg-shells-in-garden.html
Phipps, Nikki, May 9, 2016, “Milk Fertilizer Benefits: Using Milk Fertilizer on Plants,” *Gardening Know How*, http://www.gardeningknowhow.com/garden-how-to/soil-fertilizers/milk-fertilizer.htm
Tipnut, July 20, 2011, “Try Wood Ash as a Soil Fertilizer: {Good to Know},” Tipnut, http://tipnut.com/fertilizer-ashes/

Manure Tea Fertilizer

Manure tea fertilizer is a great way to create a natural liquid fertilizer that can add beneficial nutrients to the soil and will not burn plants, like some commercial fertilizers can. This style of fertilizer does have a strong odor.

Materials needed:

- a strong plastic bag
- a large rock
- some string
- dried animal manure (cow, horse, or poultry)
- large bucket (at least five gallons)

1. Choose a plastic bag that is big enough to hold the manure but still fit in the bucket when filled.
2. Carefully cut few holes in the plastic bag.
3. Put the rock into the bag to give it some weight, then add the dried animal manure and tie the bag closed with the string.
4. Fill the bucket with water and put the bag filled with animal manure into the water.
5. Let the animal manure steep for a few days.
6. After a few days the water should be a dark brown colour. Use the tea to water your garden.

Source: Burch, Monte. *The Ultimate Guide to Growing Your Own Food: Save Money, Live Better, and Enjoy Life with Food from Your Own Garden*. New York: Skyhorse Pub., 2011.

Chapter 4: GREENHOUSES

Introduction

Greenhouses are important for growing food year-round, especially during the colder months. Not all foods grow best in warmer climates, but most require protection from harsh elements. Greenhouses designed to optimize growth of plants must be designed properly and be sturdy enough to withstand harsh weather. Effective greenhouse design with minimal materials is quite possible, and those that use fewer materials often use up far less space as well. These best practices will show how building greenhouses with a minimal amount of materials and taking up minimal space is achieved.

Greenhouse Best Practices

Here are some great greenhouse ideas:

- Plastic bottle “cloche”
- Poly Tunnel or Plastic Tunnel Greenhouse
- Mini Plastic Tunnel Greenhouse
- Chinese-style Greenhouse
- Cold Frame Greenhouse

Instructions for Greenhouse Technologies

Plastic Bottle “Cloche”

A cloche is a small, simple, and easy solution to create a mini-greenhouse. It is very small, so it can only house one plant, usually a younger one. The primary purpose of a cloche is to defend younger plants that have not yet had the opportunity to become strong enough to withstand the elements, such as cold nights or mild frost in winter.

Figure 15: Plastic bottle cloche. Photo by Josie Dyck & Cathy McCarthy, 2018.

Materials needed:

- Clear two-litre plastic bottle
- Knife or scissors

1. Take a clear two-litre plastic bottle and remove the label. Cut the bottle in half across the width.
2. Take the bottom half of the bottle and turn it upside-down. Place it over the plant, pressing it into the soil to create a tight, sturdy base.
3. A cloche may need to be removed as the plant continues to grow. Be sure to check on the plant regularly to determine if the cloche should be removed.

Poly Tunnel or Plastic Tunnel Greenhouse

A poly tunnel greenhouse (also known as a plastic tunnel greenhouse) is simple to make, though it does normally require a raised bed garden. Raised bed gardens are useful, as they can prevent ground frost from affecting plants. The traditional raised bed garden requires wood to create, but other

materials such as sticks, cinder-block, rocks, or storage containers can be used as well. Before building a poly tunnel greenhouse, refer to the steps on how to build a raised bed garden first.

Materials needed:

- Thin PVC pipe or some other thin cylindrical piping that is sturdy but flexible
- A saw or knife
- A clear plastic sheet
- Nails or stakes

Figure 16: Poly tunnel greenhouse. Photo by Yuliya Gureyeva, USAID; Labeled for Reuse. *https://pixnio.com/people/male-men/farmer-displays-a-potato-greenhouse*

1. Take a pipe and plant one end firmly into the ground at the side of the raised bed garden near the corner. Bend the pipe over to create an arch and plant the other side of the pipe into the ground beside the other side of the raised bed. This should be done across the width of the garden. The pipe may need to be cut shorter to adequately create the arch, so cut it to a length that best works for the size of the garden.
2. Do the same as step one but with pipes at regular intervals until archways have been erected across the length of the garden. Arches should be no more than three feet apart.
3. Take the plastic sheet and drape it over the archways. The sheet should cover the entirety of the garden. Nail or stake the plastic sheet to the sides of the raised bed garden or to the ground beside it. Also nail or stake one end of the poly tunnel closed. Leave the other end open for watering and tending the garden.
4. When the weather gets colder, use the extra plastic material at the open end to close the poly tunnel to better keep heat in. Open that end up again when the air is warmer.

Source:
Butterfield, Mavis, 2013, “How to Build A Small Poly Tunnel,” *One Hundred Dollars A Month*, http://www.onehundreddollarsamonth.com/how-to-build-a-small-poly-tunnel/

Mini Plastic Tunnel Greenhouse

This greenhouse design is similar to the poly tunnel greenhouse, but requires much less space and fewer resources. Where the poly tunnel greenhouse is typical for raised bed gardens with multiple rows of vegetables, the mini plastic tunnel greenhouse can be done with just one or two square feet of land. As with the poly tunnel greenhouse, a raised bed is best (and recommended) for this design, although not necessary.

A mini plastic tunnel greenhouse will use different materials as well, as even thin PVC pipes or other similar material will not bend to the required shape over such a short length. Furthermore, this type of greenhouse is meant as a temporary greenhouse rather than a more permanent one, usually to keep plants warm at night to stave off frost.

Materials needed:

- metal wire or a wire cage
- plastic or tarp

Figure 17: Mini plastic tunnel greenhouse. Photo from Wikimedia Commons; Labeled for Reuse. https://upload.wikimedia.org/wikipedia/commons/b/b0/Polytunnel_Balhungie.jpg

1. Starting with a slim raised bed garden for only one row of plants, place the wire cage over the plants. Alternatively, if not using a wire cage, create several loops with the individual metal wires and place them along the garden, inserting the wire into the ground beside the slim garden to create multiple archways. The hoops are best spaced only a few inches apart.
2. Drape plastic over the wire. This is meant to be done only temporarily, as plants will need to be tended to. For that reason, the plastic will not be secured to the ground or wires. Ensure, however, that the plastic does cover the entire garden to keep heat in. Remove the cover when the weather warms up.

Source: Burch, Monte. *The Ultimate Guide to Growing Your Own Food: Save Money, Live Better, and Enjoy Life with Food from Your Own Garden*. New York: Skyhorse Pub., pp. 122-125: 2011.

Chinese-style Greenhouse

The Chinese style of greenhouse specifically takes advantage of sun angles, so the specific angle for the greenhouse will need to be modified to account for latitude and maximum incoming solar radiation absorption. Chinese greenhouses are typically built with brick or clay, but could be built with mud or other similar materials. The material's exterior must absorb and retain heat if the greenhouse is to work effectively.

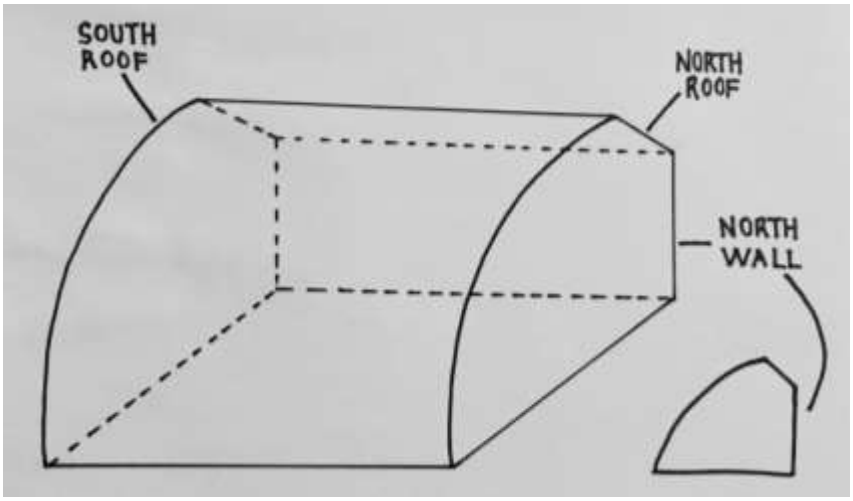

Figure 18: Chinese-style greenhouse. Illustration by Josie Dyck, 2018

Materials needed:

- Brick, clay, mud, cinder-block, or rocks
- A plastic sheet or tarp
- Grass or straw
- Sticks

1. Build up the walls first. The greenhouse only needs three walls, and the side without a wall must be facing toward the equator. The rear wall will be the tallest, and the two side walls will be sloped toward the side without a wall. The specific dimensions of the walls will be different depending on latitude. The rear wall will need to be higher for locations situated further from the equator.
2. Line the plastic along the tops of the walls and until it reaches the ground at the bottom of the two sloped walls. Secure the plastic in place.
3. Take the sticks and create a weave large enough to cover the plastic on the greenhouse. Weave grass or straw into the sticks to create a cover. Attach the weave pattern to the top of the tallest (rear) wall only. This is meant to keep heat within the greenhouse once the sun has gone down.
4. Keep the straw weave rolled up and secured at the top of the greenhouse when the sun is out and roll it out when the sun goes down.

Source: “Reinventing the Greenhouse,” *Low-Tech Magazine*, http://www.lowtechmagazine.com/2015/12/reinventing-the-greenhouse.html, accessed Dec. 30, 2016.

Chapter 5: VERTICAL GARDENING

Introduction

Vertical gardening has a great many benefits. It is a great way to gain garden space, keep plants out of reach of pests and animals, and limit the effects of ground frost. Many people live in places where ground soil is not suitable to produce promote healthy plants, so elevating the healthy soil that is used for these plants can protect them from harmful groundwater or other bacteria in the ground. There are even some plants that are simply much healthier when grown vertically, such as tomatoes and beans. When land is scarce, thinking vertically becomes a priority.

Requirements for Vertical Gardening

Vertical gardening requires that a few simple guidelines be followed. First, vertical gardens require that the vertical space receives ample sunlight. Secondly, the vertical garden needs to be built in a place that is easily accessible nor built too high, so the garden can be maintained. The supports must also be strong enough to support the weight of all of the elements being put into the containers. Finally, whatever is supporting the vertical garden must be able to absorb or resist a lot of moisture so it does not decay and fall apart over time. Following these guidelines can be fairly simple, if using areas that are already built up, such as walls.

The best vegetables to grow vertically are beans, cucumbers, peas, and tomatoes.

Ways to Grow Vertically

- Trellises
- Plastic hanging bottle garden on wall
- Gutter garden using a wall
- Free-hanging gutter garden
- Pyramid-style container garden
- Pallet tray garden
- Freestanding garden
- Radial garden
- Hanging pots
- Vertical nylon garden
- Stair garden
- Half-plastic bottle stair garden variant
- Bottle tower gardens
- Vertical PVC pipe garden

Sources:

Balcony Garden Web, “13 Plastic Bottle Vertical Garden Ideas | Soda Bottle Garden,” *Balcony Garden Web*, http://balconygardenweb.com/plastic-bottle-vertical-garden-soda-bottle-garden/, accessed December 30, 2016.
Clarke, Paul, November 4, 2015, *20 Vertical Gardening Ideas for Turning a Small Space Into A Big Harvest*, WaldenLabs: Solutions for Self-Reliance, http://waldenlabs.com/20-vertical-gardening-ideas/
FireCGun, *DIY Organic Vertical Planter*, Instructables, http://www.instructables.com/id/DIY-Organic-Vertical-Planter/?ALLSTEPS
https://www.google.com/patents/US5752341

Trellises

A trellis provides support for plants that grow up or vines – such as peas or squash. The trellis provides support for the plant and fruit and gives the plant better access to sunlight. Trellises can be made from multiple different materials, though thin wood or plywood is the traditional material used. Materials such as sticks could be used as a substitute, and fabric could also be used if a wall or other support can be utilized. Consider the end height and weight of your plant when choosing materials.

Materials needed:

- Sticks, fabric, or string
- Trellises require a wall
- Sticks require string

How to make a trellis using sticks:

1. Make sure to create this next to a wall, as the trellis will require it for support. Plant two sticks in the ground diagonally to create a cross pattern. Tie the two sticks together in the middle where they intersect. Do this multiple times, putting these crosses in the ground so that two of the ends are planted in the ground. Plant multiple crosses to create the base. Plant a number of crosses for the width of the trellis desired or needed for the plants.
2. Create more of these crosses and hoop the string around the tops of the sticks of the base crosses to build up. Continue to stack these crosses in this manner to create the trellis.

Figure 19: Trellis. Photo by Josie Dyck, 2018.

How to make a trellis using string or fabric:

1. Tie one end of a piece of string or fabric to the top of the wall or from hooks or nails in the wall, and tie the other end to the top in such a way that causes the material to dangle slightly. Depending on the width of the wall and the width of the trellis needed, place more string or fabric along the top of the wall to create a greater width. Multiple pieces of material can hang down to create the beginning of the trellis.
2. Loop more strings through the first strings hanging from the top of the wall. Tie the ends of the string together to create loops. Be sure to weave each loop of a layer together to hold them together and to keep them spread apart so plants can be weaved through.
3. The end of each layer will also need to have a piece of string or fabric on either end tying the sides to the wall.
4. Once the final layer is in place, either tie a piece of string or fabric to the ends of the bottom layer and tie them to the wall or plant sticks in the ground and tie the extra strings or fabric to those.

Figure 20: Stick trellis. Photo by Josie Dyck & Cathy McCarthy, 2018.

Plastic Hanging Bottle Garden on Wall

Figures 21a and b: Hanging plastic bottle garden. Photo by Josie Dyck & Cathy McCarthy, 2018.

Plastic bottle gardens are great because they require waste materials that are often accessible. They do also require a space to grow vertically, such as a wall. This method does not always require a wall, but will need something from which to hang the string. This design works best for vegetables that do not require deep soil, as the bottles are used on their sides and do not allow for deep root growth. Depending on the direction of the wall and direction of rainfall, they could be quite easily irrigated by the elements. Furthermore, elevating plants on a wall that is facing toward the equator will increase sunlight exposure and residual heat as the sun goes down.

Materials needed:

- Plastic two-litre bottles, labels removed, lids on
- A knife or scissors
- String or fishing line

1. Take the two-litre bottles and remove the labels if not already done. Cut out a rectangular section from the side, removing a panel that spans close to half of the side of the bottle.
2. Make sure the lid is secured and add soil.
3. Hang string from the top of the wall and loop it back up to create a sling to hold a plastic bottle. Two will be needed per plastic bottle. Place the plastic bottle's neck in one of the loops and the bottom of the plastic bottle, where there is a lip, in the other. The lip on the bottom will ensure that the bottle will not slip off of the string. For other bottles hung underneath the first, create two more loops, putting the tops on the bottle above and placing the new bottles in the new slings.
4. For other columns, stagger the bottles so they are not at the same height as the bottles on other columns.

Gutter Gardens

Figure 22: Wall gutter garden. Photo by Michael Penn, Juneau Empire. https://c2.staticflickr.com/4/3611/3488500321_9f13e5eb28.jpg

Figure 23: Free-hanging gutter garden. Photo from Wikimedia Commons; Labeled for Reuse. https://upload.wikimedia.org/wikipedia/commons/d/da/Hydroponic_strawberry_usda.jpg

Gutter Garden Using a Wall

Gutter gardens are a great way to grow multiple rows of vegetables vertically. This method will either require that gutters are already installed on the side of a building, or that there is access to materials to make gutters or troughs. While the traditional material used is a gutter, any material that creates a trough for soil and plants to sit in will do. These will also need to be mounted to walls or buildings, and the path of the sun angle will need to be taken into consideration when choosing the appropriate wall.

Materials needed:

- gutters or material cut into a trough shape (such as PVC pipe)
- nails
- a hammer or something similar
- string or fishing line

1. Take the gutter sections (or the similar material cut into troughs) and punch small holes evenly spaced to create adequate drainage so the gutters do not have too much water build-up.
2. Find a wall facing in a direction that will allow the plants to get plenty of sunlight. Use nails or something similar to fasten the string or fishing line to. Two nails will need to be placed above where the gutter will be installed and two others where the gutter will rest. Take a piece of string and tie one end to the upper nail and the other end to the lower nail. This will create a sling for the gutter to sit in. At least two will be needed, but more may be needed if the gutter is of a longer length. The gutter should not sag between the slings, and if it does, make the string short enough so that it is held upright. If using nails, ensure that the nails have been bent back after the string is tied in place to prevent the string from slipping off.
3. Alternatively, if the material's design allows for it, simply nail the gutter to the wall.
4. Once the string is at an appropriate length, install the gutter by slipping it through the strings. Once

the first gutter is installed, installation of the second one can begin.
5. Leave enough space between gutters to allow plants to receive adequate sunlight. A free-hanging gutter garden uses either gutters or material cut into the shape of a trough, just as with gutter gardens using a wall. The benefit of this version, however, is that it does not rely on a wall and it gets more access to sunlight. This version will also require fewer materials, as there is no need for nails or other fastening materials. This version does, however, require something from which to hang the garden. An overhang from a wall could work, but string will need to be tied around it so look for something small enough to tie string around while also being sturdy enough to hold multiple rows of plants.

Free-Hanging Gutter Garden

Materials needed:

- gutters or material cut into a trough (such as PVC pipe)
- string or fishing line

1. Take the gutters and punch evenly spaced holes in them to ensure adequate drainage. This will prevent the gutters from retaining too much water, which could damage plants.
2. Find a place where string can be tied around and hung from. Take two pieces of string and make them the same length. If the strings are not the same length, the gutter will hang at an awkward angle, and could even slip out. Take one piece of string and loop it around the area. Tie the two ends together to create a secure loop. Do this a second time, ensuring there is enough distance between the two loops to hold the gutter in place, on the same beam or piece of material to create the first place to hang the gutter. If the gutters are longer, more than two will be needed.
3. Take two more pieces of string at even length (more if the gutter is longer) and create another loop, this time hanging them from the already hanging gutter. Insert the new gutter into the new loops. Continue to do this using the lowest gutter on the garden until the number of desired gutters is reached. Ensure that none are touching the ground.

Stackable Container Garden

This style of vertical garden is very useful if minimal resources are available, especially if there is nothing with which to secure items to a wall or other object, or if there is simply nothing to secure items to. This style of garden simply requires plastic containers stacked in such a way to create a stack while leaving enough room for plants to grow through. This style of vertical garden can easily be done with plastic bottles of various sizes or with other plastic materials. A stackable container garden will also save space.

Materials needed:

- a series of plastic containers, roughly the same size (two-litre plastic bottles with caps still on, for example)
- a knife or scissors
- rocks

1. With plastic bottles, cut all of the bottles in half. Poke holes in the bottoms and in the caps to allow for proper drainage. Create the base by laying the bottoms of a number of the bottles in a square pattern. Lay rocks around the edges so the base does not shift.
2. Before creating the next layers, fill those already laid out with soil.
3. Next, place the tops of bottles in the spaces between the bottom pop bottles from step one. This will create the next layer of the pyramid. Place soil in these before continuing with the next layer.
4. Repeat step three until the bottles create a pyramid, with one half bottle on top. Plant the seeds in the containers once the pyramid has been fully constructed.

Figure 24: Stackable garden. Photo by PXHERE; Labeled for Reuse.
https://pxhere.com/en/photo/112361

Pallet Tray Garden

Figure 25: Pallet tray garden. Photo by Flickr User, 2012; Labeled for Reuse.
https://www.flickr.com/photos/brenneman/6870991148

The pallet tray garden is a great way to re-purpose wooden pallets. It simply requires a pallet stood on end, and trays or containers of plastic materials inserted in the nooks. This garden takes up very little space and uses scrap materials that require minimal construction.

Materials needed:

- a pallet
- plastic containers small enough to fit into the pallet's crevasses
- a hammer

1. Take a pallet and stand it on an end so that the beams run parallel to the ground. The back (or under) side of the pallet will be used for the garden.
2. Remove some boards from the front of the pallet, in between where the bottom boards are. These boards will be nailed underneath the bottom supports to create a trough that can hold soil. Once complete, the pallet will hold the containers in place.

Freestanding Garden

Freestanding gardens save space without the need for any other support. Like the pyramid-style container garden, it relies solely on the materials needed to construct it to remain erect. The key to an effective freestanding garden is a solid base, created by a raised bed garden. Traditionally, this style of vertical garden relies on wood, but PVC pipe or other materials can work just as well. This example will demonstrate how to build a freestanding garden using PVC pipe.

Figure 26: Freestanding garden. Photo by Oregon State University Flickr User, 2014; Labeled for Reuse. https://www.flickr.com/photos/oregonstateuniversity/33185459271

Materials needed:

- one-inch PVC pipe
- six-inch PVC pipe
- a saw
- materials for a raised garden bed (rocks, cinder-block, or culvert material)

1. First, start by building a raised garden bed. Create the base using the desired materials and place paper in the bottom to create a good base. Add soil.
2. Two one inch pieces of PVC pipe will be needed to create the supports for the vertical part of the garden. Insert these at either end of the raised garden bed so the freestanding portion of the garden will run the length of the garden bed. Cut each to about one metre in length. Cut grooves on the inside of both that will allow for the inserting of the six inch PVC pipe. Create these grooves at even intervals. There should be three grooves cut into each of the supports, at the same intervals.
3. Cut two pieces of six inch PVC pipe in half down the length to create troughs. Insert the PVC pipes with the openings facing upward to create troughs in which soil can be placed.

Radial Garden

This is an excellent use of minimal space to grow vine plants, such as tomatoes and beans. The vegetables are planted at the bottom and vine upwards into a trellis supported by a firm base created by the garden on which it is situated.

Figure 27: Keyhole garden. Photo by Clem Rutter, Rochester, Kent. (www.clemrutter.net); Labeled for Reuse. https://en.wikipedia.org/wiki/Keyhole_garden

Materials needed:

- rocks for a circular raised bed garden
- wire mesh
- scissors or pliers to cut wire
- string or fishing line (optional)

1. Create a circular raised bed garden. Use two rows of rocks running parallel to each other to cut the garden bed in half, and then another two parallel rows of rocks running perpendicular to the first two. These will be used to support the wire trellises.
2. Insert the wire mesh between the parallel rows of rocks. Cut the wire mesh so it starts at the edge of the raised bed and ends where the rows intersect. Do this for each of the four sides of the garden. String may be needed to tie the wire mesh together and provide support for the trellises.

Hanging Pots

Hanging pots are a simple solution to vertical gardening. In principle, they are basically just container gardens that have been hung on vertical spaces using clamps to hold them aloft. They take up less space and can look quite attractive. The most difficult part of this is finding clamps that work to hold plastic pots aloft and to find places in which these can actually be hung to allow for fastening these pots to a wall or other area. The best places to hang these will be on wooden beams, either on pallets fastened to walls, or on frames for walls. If those are not accessible, using fasteners will likely not be feasible. Beyond doing that, finding string and hanging them from rafters or other beams could work, though access to those areas will be required. The easiest way to assemble would be to create a hill or slope with mud or other material and then put the plants on the slope, using the material to hold it in place. The one thing that is universally required for this is planting containers must have adequate drainage.

Materials needed:

- containers with drainage holes
- place to hang pots that receives sufficient sunlight
- fasteners with screws (optional)
- string (optional)

Vertical Nylon Garden

Nylon gardens have great natural drainage systems built in, and because nylon can hold moisture for a time, it also helps with irrigation. This one requires an irrigation system at the top that catches water and causes it to trickle through the nylon garden. For this, look at the drip irrigation systems suggested for elevated garden spaces.

Figure 28: Vertical garden. Photo by Flickr User, 2011; Labeled for Reuse.
https://www.flickr.com/photos/wiccahwang/5481266702

Materials needed:

- solid wall
- nails (optional)
- multiple pieces of nylon fabric
- knife or scissors
- needle and thread

1. This system will require multiple pieces of nylon fabric. If there is one large piece of nylon fabric, use it as a backing for the rest of the system. Take the needle and thread and sew pockets using other pieces of nylon. These pockets should be able to hold soil.
2. Hang the nylon garden from the solid wall. Nails may be needed to secure the nylon garden to the wall.
3. Put soil in the pockets and plant seeds in these pockets of soil.
4. Install the irrigation system to the top of the wall. Water should trickle down through the nylon to irrigate the pockets.

Stair Garden

Stair gardens do not require any specific type of material to build, even though they may typically be built with wood. The stairs could be made of plastic, but the materials from the natural environment could also work quite well. Using material such as clay or mud could be a feasible option as well. The materials for this system are not listed here as materials used for vertical gardening vary greatly depending on materials available or the preferred approach.

1. Using the material of choice, create a row of steps with basins in which soil can be placed. The stair system will require backing to remain erect.
2. Put soil in each of the stairs. Plant seeds in each of the beds.

Half-Plastic Bottle Stair Garden Variant

For this variant on the stair garden, use plastic bottles. This could add security by preventing potential contamination and provides additional protection from pests.

Materials needed:

- two-litre plastic bottles
- knife or scissors

1. Cut all of the two-litre plastic bottles in half.
2. Lids removed, put soil into the top half of all of the bottles. Put them on the stairs in such a way that allows for drainage.
3. Plant seeds or small plants in the soil.

Bottle Tower Gardens

Other plastic containers can also be used if they are fairly uniform in size and shape, but plastic bottles, because they are often in great abundance, will likely make the best solution. Other than materials for the tower itself, this style of garden will require backing to support the tower.

Figure 29: Bottle tower garden. Photo by Willem Van Cotthem.
http://vuonthangdung.vn/images/stories/2014_10/huong-dan-vuon-treo-thang-dung-24.jpg

Materials needed:

- plastic bottles, same size
- knife
- scissors (optional)
- screwdriver
- wire or string

1. Be sure to set this up along a wall or somewhere where the tower has a sturdy back on which to lean. Take the first plastic bottle and cut off the bottom, just above the portion that creates the base. Keeping the lid on, turn the bottle upside-down. Cut two small holes into the bottle a couple of inches from the lid. These are drainage holes. Fill with soil.
2. Take the next bottle and do the same, only this time remove the lid.
3. Repeat step 2 a number of times until the tower reaches the desired height.

4. Wrap two pieces of string or wire around the tower and secure them to the support structure. This will keep the tower erect.
5. Take another bottle and cut it one-third of the way from the top. With the lid off, push the neck into the soil at the top of the tower. Do not add soil. This will work as a funnel to irrigate the tower.
6. Take another bottle and cut the base off. For this one, keep the lid on and punch a one-eighth inch hole into the center of the lid. Do not add soil. Take this bottle and place it on top of the tower, lid down. Fill the bottle with water, and let it slowly irrigate the tower.
7. While the tower is being irrigated, cut square sections out of the sides of the bottles filled with soil. Cut the top vertical portion of a square and the two side horizontal sections. Do not cut a line for the bottom, or soil will fall out. In this small window, plant a seedling or small plant with minimal roots. Do this for all bottles filled with soil.

Vertical PVC Pipe Garden

To make this garden, the main piece of material needed is a large PVC pipe. Soil will be planted inside to create a vertical garden. This is a great system that uses minimal amounts of material while taking up very little space.

Materials needed:

- four or six-inch PVC pipe
- saw
- pebbles
- two two-litre plastic bottles
- screwdriver

Figure 30: Vertical PVC pipe garden. Photo by Flickr User, 2012; Labeled for Reuse. https://www.flickr.com/photos/42919152@N04/6854395995

1. First, cut the PVC pipe to the desired length.
2. Dig a hole in which to insert the pipe. A fourth of the pipe's height above ground will have to be underground. For example, if the desired height above ground is four feet, one foot will need to be underground, so in total the pipe will need to be five feet in length.
3. Cut out holes in the PVC pipe in which to plant vegetables. The size of the holes will be determined by what is to be planted in them. Larger plants are not recommended.
4. Plant the pipe in the ground, adding rocks or soil to the sides as necessary to keep the pipe steady. Next, put rocks and pebbles into the pipe until the pebbles reach ground level.
5. Add soil and plant the plants into the holes cut for them.
6. Take a two-litre-plastic bottle and cut the top off, about one-third from the top. Take the lid off to create a funnel. Plant this in the soil at the top of the PVC pipe.
7. Cut the base off of the second two-litre bottle. Keep the lid on and drill a small hole into the center. Put it into the previous bottle that had been created as a funnel, and add water to start the drip irrigation process.

Chapter 6: CREATIVE HORTICULTURAL PRACTICES

Introduction

The best way to garden is not necessarily always the most straightforward way. Frost from the ground can make traditional gardening practices ineffective, and space might simply not permit conventional gardening practices. By using various creative methods, issues that arise from the environment can be prevented or mediated to design a successful garden. Available materials and aspects of the built or natural environment, though not immediately evident, could make for great places to grow fruits and vegetables. Not only do these often allow for functional gardens in places that might not normally be thought to be able to facilitate gardens, but these practices often result in attractive garden spaces that are both pleasant to look at and work with.

Various Forms of Creative Horticultural Practices

Natural and built environments often constrain conventional agricultural techniques, and hence a successful garden space may require an unconventional approach to making use of available spaces. This could range from using old bicycles and their baskets for gardening, to turning old cars into gardens, or even to finding crevices within concrete that could support the growth of plants

Raised Bed Gardening

Raised bed gardening is very important for reducing the impacts of the cold on vegetables and their roots. Raising the soil above the ground separates the plants from the colder ground, so raised beds are especially useful in colder climates. Raised beds can also be useful for promoting other best practices when combined with greenhouses and vertical gardens.
The materials for building a raised bed garden vary widely, though newspapers or cardboard will be needed to line the bottom of the raised bed. Soil will also be necessary to fill the bed once it is complete. Examples of useful materials: wood, cinder block, steel, rocks.

1. Decide what size you would like your garden bed to be. Build a base out of your chosen material with those dimensions. Raised bed gardens can also use materials that have a set perimeter, but will still need a base. The base material can be something other than what the sides of the garden are made from.
2. Next, build the sides of the raised bed garden. It may be best to keep the raised bed garden no deeper than six to ten inches, as this makes gardening while sitting much easier and more accessible. This also makes it easier for people who have a more difficult time moving around, especially the elderly, to garden in comfort as it allows them to sit while gardening.
3. Next, line the bottom of the bed with cardboard or newspaper. This not only helps to keep the soil in, but also keeps the bed warmer. The lining will also keep pests and weeds from getting through the bottom of the garden.
4. Then add the soil. Level it out, and also ensure not to fill the garden all the way to the top, as plants will be added.

   Source: Peterson, Jenny, 2013, “8 Materials for Raised Bed Gardens,” *houzz*, http://www.houzz.com/ideabooks/16676705/list/8-materials-for-raised-garden-beds

Figure 31: Raised bed garden made with sticks. Photo by Patrick Montero/Rodale, Inc. http://3u0gdv3vukuf15vp9312siwh2cg.wpengine.netdna-cdn.com/wp-content/uploads/2016/03/5beds-wattle-885-rodale.jpg

Container Gardening

The greatest benefit to container gardening is that it takes up significantly less space than other forms of gardening. On top of that, container gardens can be stored anywhere. Most container gardens are specifically designed so they can fit inside the home, while others have been designed to be safe from pests or to raise the plants above the ground altogether, as in the case with vertical container gardening. For this method of gardening, simply find a container that suits your needs and that can fit in the space available. Fill it with soil, plant, irrigate, and let it grow. These types of plants can also make fun small projects for people of any age, and can add some green to living spaces.

Here are some items that can make for great container gardens:

- plastic bottles, two-litre are best
- luggage/suitcases
- bicycle spare parts, particularly the baskets
- rain gutters
- milk jugs
- glass jars
- troughs
- food tins

Figure 32: Using old tins for container gardens. Photo by Josie Dyck & Cathy McCarthy, 2018

As the list above shows, container gardening is very diverse and can be a very creative way to effectively use minimal space and resources to grow fruits and vegetables. On this page, and on following pages, multiple pictures will show just how diverse container gardening is.

This trough garden shows just how versatile gardening can be when old items are utilized. Not only is it an amazing container, also working as a raised bed garden, it can effectively work for all sorts of vegetables and fruits. The material is also highly resistant to pests, and with some minor work, can easily have effective drainage.

Figure 33: Trough garden. Photo by Flickr User, 2009; Labeled for Reuse.
https://www.flickr.com/photos/daryl_mitchell/3665949250/

Figure 34: Bottle garden. Photo by Josie Dyck & Cathy McCarthy, 2018

Bottle gardens make for great vertical gardening solutions, as well as easily condensed gardening solutions for vegetables that do not require growing deep roots. Root vegetables may be more difficult to grow in plastic bottles, but all others can thrive in these gardens.

Container Gardening Using Milk Jugs

Because milk jugs are so large, they can be used to house all sorts of different vegetables, even root vegetables. Simply cut the milk jug in half or cut the top off and fill with soil to create a garden. Milk jugs that have the top cut off are quite deep, so they can easily house root vegetables. They can house four or five carrots per jug, about three onions per jug, and other root vegetables of similar sizes quite easily.

Source: Baley, Anne, *What Vegetable Plant Can Grow in A Gallon Milk Jug?*, SFGate, http://homeguides.sfgate.com/vegetable-plant-can-grow-gallon-milk-jug-45483.html, accessed November 14, 2016.

String Trellises Using Raised Bed Gardens

String trellises can be used to support vine plants using nothing more than a raised bed garden, some sticks, and string. Construct frames using sticks and come up with creative ways in which to tie string to them to encourage vine plants to grow along them and grow upward. The string can go vertically or horizontally, depending on desired outcomes, materials available, and perhaps the type of vine plants. Tomatoes are the most common plant to be grown with string trellises, but others such as peas, beans, and grapes can be grown on trellises as well.

Chapter 7: PEST CONTROL

Introduction

Pest control is important when gardening, because pests can contaminate soil or eat plants and make them inedible or cause them to die. Pests that eat into the roots of plants are especially damaging, so steps will need to be taken to deter them. There are multiple methods, some of which involve mulching, which was detailed in a previous chapter, and others are simple solutions that require maintaining the garden or taking small steps to deterring critters.

Not all insects are harmful to a garden, however. Some can help plants thrive. Knowing which ones are helpful and which ones are not is a good place to start, but beyond that, learning to weed out the unwanted critters is essential to maintaining a successful and healthy garden.

Insects and Other Creatures to Encourage

Not all insects will be harmful to plants, and some are actually beneficial. Here is a list of critters to keep around in the garden:

- Earthworms – worms are very healthy for soil. They naturally produce compost, and can aid in keeping soil the way plants like it.
- Birds, bats, toads, and snakes – these critters eat insects, slugs, and other harmful pests. For them to stay, though, they will need food, water, and shelter. Make sure your garden has plenty to support them and keep them around. Effective ways of providing water include bowls of water or ponds.
    - Build a birdhouse to keep birds around. Birdseed or other feeds for birds will attract them, and should be used with the birdhouse. Along with eating insects, birds may eat seeds and seedlings, so either cover seeds to protect them from the birds or wait until the plants sprout to attract more birds. A couple of weeds will also attract birds: chickweed and Lamb's quarters.
    - Bat houses look like flattened birdhouses, but with a thin slot for the entrance. Bats will also just stay in trees.
    - Toads like covered, moist areas. Take a clay pot with a chipped rim and place it near a water source (such as one of the bowls set out) upside-down.
    - Snakes love rocks and pebbles, so place those around the outskirts of the garden. Leave a bit of space for the snakes to crawl through.
- Insects – ground beetles, honeybees, lacewings, ladybugs, praying mantis, spiders, syrphid flies (also known as flower flies or hoverflies), tachina flies, wasps, and yellowjackets can all benefit a garden.
    - Use flowers to keep insects in the garden. Either plant flowers to attract insects, or let some of the vegetables flower to attract these insects. This will also add a pleasing aesthetic to the garden. Though weeds are mostly a negative sign, some can also attract insects to the garden. Here are some weeds that can help with that:
        - Corn spurry
        - Queen Anne's lace
        - Wild mustard
        - White clover

Dealing with Pests

Other than using the animals listed on the previous page to limit harmful insects' presence in the garden, other methods can be used to keep pests at bay. Here are a few simple methods to employ:

- For mice, set mouse traps. Snakes will help keep mice at bay.
- For slugs, use either a dish of beer or a board to attract them. This will cluster them into one location, making them easier to find and destroy.
- Use covers, such as the cloche from the greenhouses chapter, to prevent insects from laying eggs or larvae on plants.
- Flytraps will attract certain pests. Insects will stick to them and die.
- Also till the soil at the beginning of every season. This will expose any insects, larvae, or eggs that had been planted under the soil. The elements will help to destroy them.

Benefits of Weeds

As noted on the previous page, weeds can be beneficial for attracting certain creatures that can help keep pests at bay. Beyond that, some weeds are also edible. Here is a list of weeds that can be used as food in cooking:

- nettles
- dandelions
- purslane
- lamb's quarters
- burdock

Source: Abbott, Catherine. *The Everything Grow Your Own Vegetables Book: Your complete guide to planting, tending, and harvesting vegetables*. Avon, MA: Adams Media, pp. 184-203: 2010.

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