RODALE INSTITUTE™

VERTICAL GARDENING

IN AN URBAN ENVIRONMENT

WRITTEN BY RICK CARR

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LETTER FROM THE EXECUTIVE DIRECTOR

Rodale Institute has been dedicated to making the world a better place through agriculture since J.I. Rodale first chalked our motto on a blackboard in 1947: Healthy Soil = Healthy Food = Healthy People®. Our motto continues to drive all Rodale Institute projects. It is the touchstone against which we test all of our efforts. Even then, J.I. understood that healthy soil is the foundation for growing healthy food. We are as committed today as ever to J.I. Rodale's conviction and the work Robert Rodale continued when we planted our roots on a 333-acre farm outside Kutztown, Pennsylvania.

Urban centers are commonly described as "food deserts" where access to fresh food is limited. As we are in close proximity to the cities of Reading, Allentown and Philadelphia, we can see there is a serious need to increase local, healthy food production within city limits. However, two obstacles exist when growing food in urban environments: limited space and soil contamination.

This particular project found us addressing both obstacles. In an environment dominated by paved surfaces, finding space and the soil needed for plant production can be difficult. What's more, urban soils are often contaminated by toxic substances from past or present commercial industries. Lead for example, had been an additive in paint and gasoline for decades until it was realized that lead can have a damaging effect on adolescent brain development.

Rodale Institute has developed a vertical gardening system in an attempt to avoid exposure to harmful substances that can be found in urban soils and increase our capacity to produce fresh, healthy food in the city. We have demonstrated their use and effectiveness in Allentown and Philadelphia.

We are committed to supporting farmers, both rural and urban, and this document is a testament to our outreach and support. Through first-rate scientific research, outreach, and education, we hope to support all farmers in their journey towards a more sustainable food system.

Jeff Moyer
Executive Director

RODALE INSTITUTE OVERVIEW

As a 501(c)(3) non-profit, Rodale Institute, located in Kutztown, Pennsylvania is dedicated to pioneering organic farming through research and outreach. Rodale Institute was founded in 1947 by J.I. Rodale working with the philosophy that, "Healthy Soil = Healthy Food = Healthy People®." For over 70 years, we've been researching the best practices of organic agriculture and sharing our findings with farmers and scientists throughout the world, advocating for policies that support farmers, and educating consumers about how going organic is the healthiest option for people and the planet.

ACKNOWLEDGEMENTS

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1 BACKGROUND

Urban areas account for 3% of the nation's land area but contain 80% (over 250 million people and rising) of the population, according to the United States Census Bureau. A high concentration of people combined with limited land suitable for crop production make it challenging for urban residents to gain access to fresh, healthy food. This is what is commonly referred to as a "food desert," where almost all the food consumed in the city is trucked, shipped, trained, or flown in from outside locations. What's worse is the condition and quality of the food after it has arrived—fruits and vegetables can become damaged during shipment or arrive close to or past expiration. Given this situation, there is a rising interest to grow fresh produce within city limits.

Like any other food production system, growing produce in an urban environment is not without its challenges. In an area dominated by paved surfaces, the first challenge is locating land suitable for food production. It may even be difficult to find suitable space large enough to place a few potted plants, box plots or raised beds in one's own backyard. Reclaiming abandoned lots, parks, and grassy areas is a step in the right direction for establishing larger, communal areas for food production; however, these areas are often owned by the city, which can cause logistical and liability issues for gaining access despite good intention. It may take months or even years to narrow down options of abandoned lots because there can be a surprisingly high number of them in the city. The city of Philadelphia, for example, has an estimated 40,000

> ***A high concentration of people, combined with limited land suitable for crop production, make it challenging for urban residents to gain access to fresh, healthy food.***

abandoned lots. Do not be discouraged, however, as there are a growing number of community and city officials willing to assist in the process of acquisition.

Urban centers have been and are associated with industry and commerce. Decades of industrial and commercial activities have taken a toll on urban land and, unfortunately, urban soils are often contaminated with substances that can be toxic to human health. Take lead, for example; it was used in paint for decades as a pigment, to speed drying, and to increase durability, until it was discovered to have negative impacts on adolescent brain development and function. Although lead has been banned from paints in the U.S. since 1978, the health and environmental impact from widespread applications of lead paint still exists and those with the greatest risk of exposure are city residents due to its prevalence. Lead was also a byproduct of the combustion of leaded gasoline. It is safe to assume, therefore, that areas with a historically high concentration of automobiles will have high concentrations of lead near roadways. Considering we are only looking at lead in this instance, you may quickly realize that the environmental quality of urban soils might not be ideal for agriculture.

With an increase in interest for urban gardening, agriculture, and producing fresh, healthy food within city limits, greater attention has been given to soil safety and minimizing the risk of exposure to toxic substances. In 2014, the Food Advisory Council, under the Philadelphia Mayor's Office, established a Soil Safety Working Group consisting of city officials, governmental agents from USDA, EPA and Center for Disease Control, university students and faculty specializing in soil contamination, community leaders and activists, agricultural experts and advisors, and urban farmers. Their goal was to develop action steps for:

1. Identifying sites for food production,
2. Evaluating risk levels in the soil, and
3. Outlining best practices for safe food production.

The first step requires a site history report, also known as environmental due diligence, that identifies past uses of the lot. This will help determine potentially hazardous sites and help guide the second step of choosing which soil contaminants to test for when evaluating risk levels. Soil test results will then be used to decide best plant production practices such as growing directly in the soil, establishing raised beds, building box plots or abandoning the site from consideration altogether.

When space is limited and there is a risk of exposure to soil contaminants, vertical gardening becomes an attractive alternative for safely growing food within urban environments. Rodale Institute has been demonstrating the use and effectiveness of "Growing Towers" (simple structures where the space available for plant production is built vertically in a column or rectangular wall) for growing fruits, vegetables, herbs, and flowers in a variety of urban settings. This document presents the costs and benefits, successes and failures, and an overview of how Rodale Institute's Growing Towers may impact urban gardening and agriculture.

2 URBAN SOIL SAFETY

U.S. cities are concentrated with business and industry. For the last 300 years, industry has ebbed and flowed but continues to grow steadily as demand for materials and services increase. Advanced technology also drives new materials and the benefits they may carry for the populace. However, new materials and industry may result in hidden costs and accidental consequences; much of these are imposed on individuals, communities, and the environment.

Artifacts from past industries can be found in city soils all around the U.S. They come in the form of chemical substances that are often toxic to human health. Some of the more notable substances include heavy metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and polychlorinated biphenyls (PCBs). Toxicity to human health can vary among these substances but a number of them have been labeled as carcinogenic. The production and use of these harmful compounds has, in some cases, dramatically decreased during the last half century, or else they were banned entirely. Unfortunately, due to their chemical nature, they have persisted in the environment and often can be detected in urban soils.

Common sources of harmful soil contaminants:

- **Heavy metals (e.g. lead and arsenic):** paint, pesticides, leaded gasoline, building materials, and industrial operations. Heavy metals, by their nature, tend to persist in the environment and will not break down. Arsenic in particular is a common artifact from the burning of coal. In older cities, especially cities with a past of heavy manufacturing, arsenic concentrations in the soils are ubiquitous, and often at higher than state and federal action levels.
- **Polycyclic aromatic hydrocarbons (PAHs):** burning various organic substances such as coal, and operations conducted at former industrial/manufacturing facilities.
- **Volatile and semi-volatile organic compounds (VOCs and SVOCs):** fossil fuels, paints, chlorinated solvents, industrial and commercial operations, as well as the highly regulated and currently banned chlorofluorocarbons (CFCs)
- **Polychlorinated biphenyls (PCBs):** once used as coolant fluids in electrical apparatus (such as transformers), pesticide extenders and added to other substances such as paint, caulking, adhesives and wood floor finishes.

Although it may seem inconceivable in our current system of environmental and zoning regulations, shortly after the Civil War, during the Industrial Revolution, there was very little in the way of environmental consciousness. Residential and industrial areas were often comingled. There was also very little in the way of proper waste disposal. Areas that needed to be brought up to grade or, in other words, have the soil leveled out, were often filled in with materials on hand—materials that may now be considered toxic or hazardous. In some of our older cities this "urban fill" is pervasive, contaminated, unmapped, and possibly occurs in areas where recent development has hidden industrial scars from the past. This makes the need for proper environmental due diligence (i.e. reasonable steps taken by a person in order to satisfy a legal requirement) extremely important when considering locations for urban agricultural activities.

ACTION STEPS FOR URBAN SOIL SAFETY AND FOOD PRODUCTION:

1. Conduct a site history and environmental due diligence.
2. Test for soil contaminants using the information from the site history.
3. Determine the best management practices to minimize or mitigate the risk of contaminant exposure.

Recent interests in food production in urban environments have prompted a re-evaluation of soil safety, economic incentives, and the best practices for urban gardening and agriculture. The first step when choosing a location for food production is to conduct proper environmental due diligence and determine the site history. This may include examining historical records, aerial photographs, and Sanborn maps, and conducting interviews with current/former site owners. Understanding the history of the site will identify "red flags" such as industries or commerce that were known to have generated the toxic chemicals mentioned previously. When conducting a due diligence, it's important to search as far back as possible because some of the soil contaminants can persist even from industries dating back to the 1800s.

Environmental due diligence at the site may discover potential risks in the soil. This will prompt soil testing, the second step in urban soil safety. However, this raises additional questions. Should testing be mandatory? Is there a screening mechanism that would eliminate the need to test? At what level of concern should testing occur? How many samples should be collected and how should they be distributed throughout the site? Ideally, you'll want to find the worst case scenario, so you can make your decisions based on the highest risk scenario. Additionally, what is the action level (i.e. the concentration of a contaminant in soil that, depending on use, can cause a deleterious effect on certain segments of the population) that you are comfortable with? In other words, what risk level are you comfortable with when it comes to putting food into your body?

It should be noted that different compounds have different action levels and they may react differently depending on how they are encountered in the environment. It is important to understand not only what you are testing for, but why. In any case, if soil testing should occur then your environmental due diligence will act as a guide for what to test. County extension agents, relevant university faculty, city, and government officials from the EPA and the PA Department of Environmental Protection can provide recommendations on collecting soil samples and where to submit them. If it is determined that sampling will be extensive, it could be advantageous for you to seek the assistance of an environmental consultant.

SOIL TESTING LABORATORIES:

- Penn State Agricultural Analytical Services Laboratory
- PA Department of Environmental Protection
- Cornell Nutrient Analysis Laboratory

Note: there are many suitable commercial laboratories. Some questions you will want to consider before choosing a laboratory are:

- Is this an accredited laboratory in the state where the sample has been collected?
- Can this laboratory analyze for the compounds in question, and can the laboratory reporting limit meet state and federal action levels?

Soil testing results will reveal actual soil contaminants, but what are the risk levels? There are a number of sources that list acceptable levels of soil contaminants for growing food for human consumption, as well as listing levels of contamination that can be harmful when exposed to humans. If the risk of exposure is "none" or "very low," then there is no need to be concerned about exposure; however, if your soil reveals low or elevated contaminant levels then some action is needed based on the level of contamination. Refer to the list of sources for soil contaminant

SOURCES FOR SOIL CONTAMINANT RISK LEVELS:

- PA Department of Environmental Protection
- US EPA Soil Screening Levels
- US EPA Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices
- University of Vermont Agricultural Extension
- World Health Organization
- Agency for Toxic Substances and Disease Registry

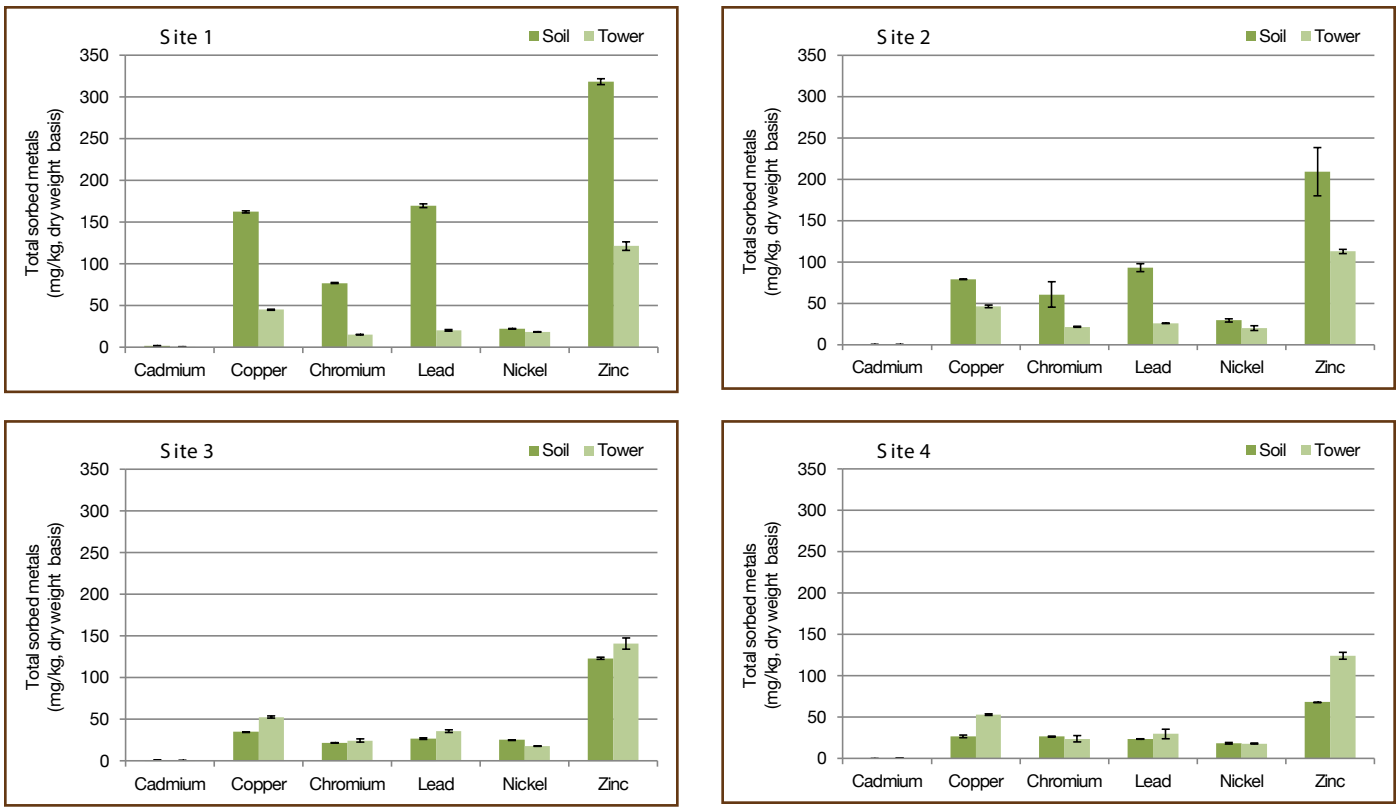
risk levels and recommended actions on page 6. If you are unsure with your testing results, then it is best to consult the testing laboratory for more information.

In the event that contaminants are present in the soil at elevated levels, the next step is to identify best management practices that will mitigate exposure risks. There are a number of factors that determine whether a plant will up-take various soil contaminants such as type and concentration of contaminants, soil pH, type of plant, etc. In most cases, plants will not up-take contaminants and distribute them to edible plant parts (this is called bioavailability of a contaminant). The greatest risks of exposure are often from disturbing the soil, breathing in dust, and coming in direct contact with the soil through either incidental ingestion or skin contact. This will occur when tilling or preparing the soil for planting, incorporating soil amendments, and removing unwanted plants or dead plants at the end of the season. There are a number of gardening and agricultural practices that will minimize the risk of exposure to soil contaminants. In some cases, just segregating areas of contaminated soils from acceptable soils will create enough of a soil medium for safe plant production. Raised beds can reduce disturbances and plant growth into the urban fill or impacted native soil. Box plots with protective underlying barriers will reduce exposure to the impacted native soil even more than raised beds. Amending the soil with compost will minimize the movement of contaminants during rain events. Other best management practices can be found at your local county extension office, US EPA Brownfields Program, PA Department of Agriculture, or PA Department of Environmental Protection.

Rodale Institute has been exploring alternative urban soil safety practices for gardening and agriculture. When space is limited for traditional raised beds and box plots, vertical gardening becomes an attractive alternative. There are a number of different techniques for vertical gardening, which are reviewed in the next section. However, regardless of space, soil quality is of upmost concern, especially in an urban setting. The main objective for vertical gardening is to build a structure that will permit plant growth vertically, with one plant growing above another. By using proper environmental due diligence, sampling when deemed

necessary, and mitigating soil contamination where appropriate, vertical gardening can simultaneously resolve two concerns with urban food production: limited space and risk of exposure to harmful soil contaminants.

What follows is an example of soil sampling. Soil samples were collected from four different urban sites in either Allentown or Philadelphia. Samples were analyzed for heavy metal content at Penn State Agricultural Analytical Services Lab, State College, PA. The table below shows the risk levels set by four different agencies. Bars in the charts below represent standard deviation.



Contaminant Risk Levels

	EPA RSL[1]	PA DEP[2]	Agency for Toxic Substances and Disease Registry
Units:	mg/kg (ppm)	mg/kg (ppm)	
Cadmium	78	1.2	0.04 ppm (children[3]), 0.005 ppm (lifetime exposure), 5 µg/m^3 [4]
Copper	3,100	8,100	1.3 mg/L (drinking water); 0.1 mg/m^3 fumes and 1.0 mg/m^3 dust[4]; dietary allowance vary by age[5]
Chromium (III)	Not available	190,000	0.005 mg/m^3 (soluble[6]) and 0.0001 mg/m^3 (insoluble[6])[7]
Chromium (VI)	230	4	0.005 ppm/day (inter.[8]) and 0.0009 ppm/day (chron.[9])[10]
Lead	Not available	500	Not available
Nickel	860	4,400	0.0002 mg/m^3 (inter.) and 0.00009 mg/m^3 (chron.)[7]
Zinc	23,000	66,000	0.3 ppm/day (inter. and chron.)[10]

[1] Environmental Protection Agency Risk Screening Level
[2] Pennsylvania Department of Environmental Protection Residential, Direct Contact Numeric Value, 2017
[3] Exposure for up to 10 days in drinking water
[4] Limited workers' exposure for 8-hour day, 40-hour week
[5] 340 µg (ages 1-3), 440 µg (ages 4-8), 700 µg (ages 9-13), 890 µg (ages 14-18), and 900 µg (adults)
[6] Types of particulates
[7] Intake through inhalation
[8] Intermediate exposure = 15–364 days
[9] Chronic exposure = more than 1 year
[10] Taken orally; risk is less for inhaled mists and particulates

3 VERTICAL GARDENING IN AN URBAN ENVIRONMENT

There are several different techniques for vertical gardening. Two commonly practiced systems either involve hydro- or aquaponics or designing a system of several containers, each holding one plant at a time, positioned vertically on a frame. Both systems have proven successful for urban food production. However, hydro- and aquaponic systems require significant infrastructure and know-how and both methods lack a significant soil component. For over 70 years, Rodale Institute has emphasized the importance of soil health, identifying soil characteristics and processes that are necessary for healthy food production. With this concept in mind, Rodale Institute has developed a vertical gardening technique with soil as a central element to plant production, similar to organic, in-ground gardening and agricultural practices.

Rodale Institute developed Growing Towers for urban gardening and agriculture that address both issues with space limitations and potentially contaminated soil. Welded wire is shaped into a cylinder, lined with black woven plastic and then back-filled with compost-amended soil. Plants can be transplanted into the sides of the Growing Tower while the top can be planted as you normally would in the ground. When space is limited for raised beds or box plots, Growing Towers provide area for plant production vertically. On some Growing Towers, the area available for planting can be greater than standard 4' x 8' foot box plots. Growing Towers can be constructed from three to six feet tall. In situations where the underlying soil is suspected to be contaminated with substances toxic to human health, additional black woven plastic can be placed under the Growing Tower to prevent soil from moving between the Growing Tower and the underlying soil. Thus, Rodale Institute Growing Towers not only increase space vertically for fruit, vegetable, herb, and flower production but minimize the risk of exposure to harmful soil contaminants as well.

> ***Healthy Soil = Healthy Food = Healthy People®***

The use and effectiveness of Growing Towers has been demonstrated under several urban conditions. A variety of plant types including fruits, vegetables, herbs, and flowers have been grown in Growing Towers with mixed results—some plants are less suitable than others or otherwise require additional care and maintenance. For instance, tomatoes grow well in Growing Towers but require trellising to prevent them from lying on the ground or overtaking plants growing below. Growing Towers are adaptable to hard or soft surfaces and the structures can be free-standing. Several techniques were tested to aid in irrigation, which are discussed later. While it is more ideal to produce fruits and vegetables in the ground as nature has intended, this is often not possible in environments dominated by paved surfaces, limited space, and a high potential for soil contamination. In that case, Growing Towers become an attractive alternative for safe and healthy food production.

4 HOW TO BUILD A GROWING TOWER

Several prototypes of Growing Towers have been tested by Rodale Institute. The following instructions are for building a Growing Tower that Rodale Institute has determined to be the least labor-intensive. They can be completed by one person alone. Other materials can be substituted as needed or as preferred.

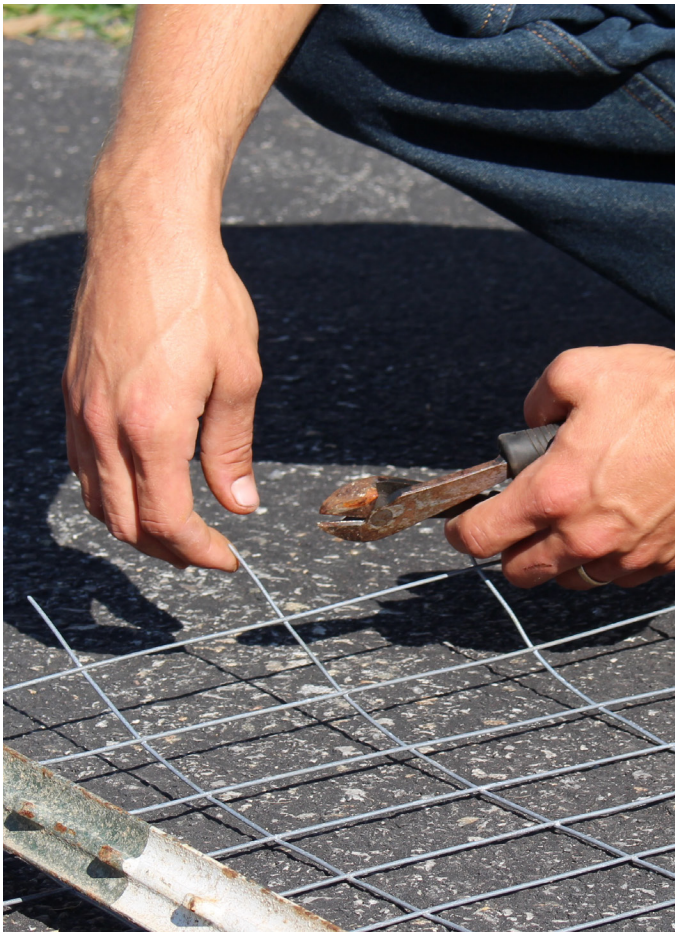
Before starting, choose the height, diameter and the location of the Growing Tower. Growing Towers 3 or 4 feet tall are generally recommended, but they can be built as tall as 6 feet. Taller Growing Towers will require internal support using T-posts and there is a greater risk for taller Growing Towers to lean after they are built.

The diameter of Growing Towers can vary between 1 and 3 feet. 3-foot diameter Growing Towers require more building materials, soil and space but offer more surface area for plant production. Growing Towers between 2 and 2½ feet wide are ideal based on Rodale Institute's experience.

Choose a location for the Growing Tower that provides adequate sunlight for plant growth. It is acceptable to build Growing Towers directly onto paved surfaces, but it is recommended not to exceed 4 feet tall and use a diameter no less than 2 feet.

MATERIALS NEEDED:

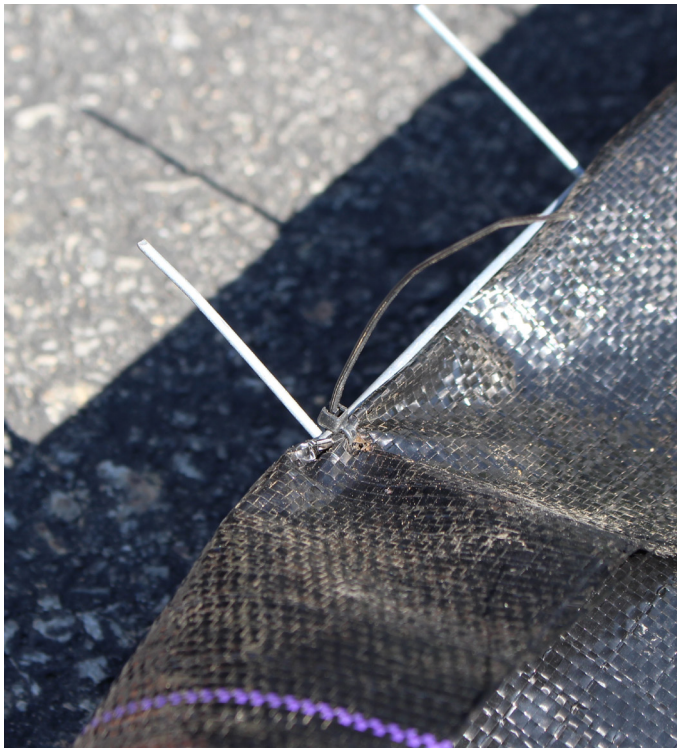
- Welded wire, 2" x 4" openings, 3' to 6' wide (for the height of the Growing Tower) and 6' to 13' long depending on intended diameter of the Growing Tower
- Black woven plastic ground cover, slightly larger dimensions than welded wire
- T-post, 3' to 5' long depending on the height of the Growing Tower
- Compost-amended soil, no greater than 50% compost by volume
- Water source
- Irrigation materials (discussed later)
- Wire cutters
- Stake pounder and safety helmet
- Scissors
- Work gloves
- Zip ties
- Hole punch



1. Cut welded wire to the desired height and diameter. Use wire cutters and protective work gloves for this task. On one end of the length, cut the wire as close to the edge of the joining cell as possible so as not to leave any excess wire. Do the opposite to the other end of the length of wire so that the excess horizontal wire can be used to secure the two ends together. Use the table below to determine the size of your Growing Tower.

Diameter	Length of welded wire
1 foot	3 feet 2 inches
1 ½ feet	4 feet 9 inches
2 feet	6 feet 4 inches
2 ½ feet	7 feet 10 inches
3 feet	9 feet 5 inches

2. With the welded wire cut and laid flat on the ground, fit the black woven plastic to the size of the wire. Leave an extra 2 inches on each end of the length of the welded wire.



3. Use Zip ties and a hole punch to tie the black woven plastic to the inside of the welded wire frame.

4. Fold 2” to 4” of woven plastic over the top of the Growing Tower so that the folded material is on the outside of the Growing Tower and the remaining material is on the inside.

5. Zip tie one end of the length of the Growing Tower first, and then the other. Secure the woven plastic every 6” to 12”. **Note:** Zip ties are not needed for the bottom of the Growing Tower.

6. Zip tie the top of the Growing Tower where the fold is located.

7. Shape the Growing Tower into a cylinder and place the Growing Tower in the desired location.

8. Using extreme caution, bend the excess wire on one end of the cylinder to secure it to the other. Alternatively, Zip ties can be used to secure the two ends of the cylinder.

9. Fill the Growing Tower with clean (free of contaminants), compost-amended soil. If compost is not available use clean topsoil; however, compost-amended soil will provide valuable plant nutrients and beneficial microorganisms for multiple growing seasons.

SOME THINGS TO NOTE

- Prepare materials for irrigation if applicable and install irrigation system while filling the Growing Tower. More details about irrigation are discussed later.
- If placing on soil surfaces, it is recommended to drive a T-post into the ground, while wearing a safety helmet to avoid potentially serious head injury, before filling with soil. The T-post will provide additional structural support. Drive the T-post at least 1 foot into the ground.

Most of the building materials for Growing Towers are available at local hardware stores. Black woven plastic may be difficult to find at hardware stores but is available through farm and garden suppliers.

Nolt's Produce Supplies was the source for Rodale Institute's black woven plastic. The costs for materials will vary by store and those reported in this booklet are from Nolt's Produce Supplies, Lowe's, and Weaver's Ace Hardware.

3-foot tall, 2-foot diameter Growing Tower

- **3-foot welded wire (2" x 4" openings)---------- $ 30.00**
  - » 50 feet long
  - » 6.5 feet per tower
  - » 7.7 Growing Towers per roll
  - » Cost per Growing Tower (7) $ 4.29
- **4-foot black woven plastic ground cover ---------- $ 56.00**
  - » 300 feet long
  - » 7 feet per Growing Towers
  - » 42.9 Growing Towers per roll
  - » Cost per Growing Tower (42) $ 1.33
- **Compost-amended soil per cubic yard ---------- $ 30.00**
  - » 9.4 ft^3 (0.35 yd^3) soil needed per Growing Tower
  - » 2.9 Growing Towers per cubic yard
  - » Cost per Growing tower (2) $ 15.00
- **T-post (each)---------- $ 8.48**
  - » 6.5 feet long
  - » ½ T-post per Growing Tower
  - » Cost per Growing Tower (1) $ 4.24
- **Zip ties ---------- $ 4.99**
  - » 100-pack
  - » 25 ties per Growing Tower
  - » 4 Growing Towers per pack
  - » Cost per Growing Tower (4) $ 1.25
- **Total for all materials---------- $ 129.47**

4-foot tall, 2-foot diameter Growing Tower

- **4-foot welded wire (2" x 4" openings)---------- $ 45.00**
  - » 50 feet long
  - » 6.5 feet per tower
  - » 7.7 Growing Towers per roll
  - » Cost per Growing Tower (7) $ 6.43
- **4-foot black woven plastic ground cover ---------- $ 56.00**
  - » 300 feet long
  - » 7 feet per Growing Towers
  - » 42.9 Growing Towers per roll
  - » Cost per Growing Tower (42) $ 1.33
- **Compost-amended soil per cubic yard ---------- $ 30.00**
  - » 12.6 ft^3 (0.47 yd^3) soil needed per Growing Tower
  - » 2.1 Growing Towers per cubic yard
  - » Cost per Growing tower (2) $ 15.00
- **T-post (each)---------- $ 6.98**
  - » 5.5 feet long
  - » 1 T-post per Growing Tower
  - » Cost per Growing Tower (1) $ 6.98
- **Zip ties ---------- $ 4.99**
  - » 100-pack
  - » 25 ties per Growing Tower
  - » 4 Growing Towers per pack
  - » Cost per Growing Tower (4) $ 1.66
- **Total for all materials---------- $ 142.97**

5-foot tall, 2-foot diameter Growing Tower

- **5-foot welded wire (2" x 4" openings)---------- $ 50.00**
  - » 50 feet long
  - » 6.5 feet per tower
  - » 7.7 Growing Towers per roll
  - » Cost per Growing Tower (7) $ 7.14
- **6-foot black woven plastic ground cover ---------- $ 56.00**
  - » 300 feet long
  - » 7 feet per Growing Towers
  - » 42.9 Growing Towers per roll
  - » Cost per Growing Tower (42) $ 1.33
- **Compost-amended soil per cubic yard ---------- $ 30.00**
  - » 15.7 ft^3 (0.58 yd^3) soil needed per Growing Tower
  - » 1.7 Growing Towers per cubic yard
  - » Cost per Growing tower (1) $ 30.00
- **T-post (each)---------- $ 6.98**
  - » 5.5 feet long
  - » 1 T-post per Growing Tower
  - » Cost per Growing Tower (1) $ 6.98
- **Zip ties ---------- $ 4.99**
  - » 100-pack
  - » 25 ties per Growing Tower
  - » 4 Growing Towers per pack
  - » Cost per Growing Tower (4) $ 1.66
- **Total for all materials---------- $ 147.97**

Note: the number in paranthesis on the "Cost per Growing Tower" line indicates how many Growing Towers can be built in full using the listed material.

5 PLANTING A GROWING TOWER

Once a Growing Tower has been filled with clean, compost-amended soil, it is ready for planting. However, it's not unusual for the soil to settle 6" to 12" during the weeks after filling, especially after rain events, so allow soil to settle a week or two and then refill the Growing Tower. Do not fill the Growing Tower beyond an inch from the top. If the Growing Tower is overfilled, water tends to flow over the sides rather than infiltrate into the soil column.

There are a number of different plants that can be grown in Growing Towers. For three growing seasons, Rodale Institute has been successful at growing a wide variety of fruits, vegetables, herbs, and flowers. Some plants will do better than others, and some may require additional care and maintenance in order to maximize production. It's important to note that seedlings can be transplanted into the sides or top of the Growing Tower while direct seeding can be done in the top only. Seeds planted into the sides of the Growing Tower will not emerge.

Area available for planting in Growing Towers

Height (ft)	Diameter (ft)	Area available for planting (ft^2)		Total (ft^2)
		Sides	Top	
3	1.5	14.1	1.8	15.9
	2.0	18.9	3.1	22.0
	2.5	23.6	4.9	28.5
	3.0	28.3	7.1	35.4
4	1.5	18.9	1.8	20.7
	2.0	25.1	3.1	28.2
	2.5	31.4	4.9	36.3
	3.0	37.7	7.1	44.8
5	1.5	23.6	1.8	25.4
	2.0	31.4	3.1	34.5
	2.5	39.3	4.9	44.2
	3.0	47.1	7.1	54.2
6	1.5	28.3	1.8	30.1
	2.0	37.7	3.1	40.8
	2.5	47.1	4.9	52.0
	3.0	56.6	7.1	63.7

Fruits that have been attempted in Growing Towers

Fruit	Direct seeded	Transplanted	Side of Tower	Top of Tower
Tomato, cherry		✓	✓	✓
Tomato, roma		✓	✓	✓
Tomato, beefsteak		✓	✓	✓
Pepper, bell		✓	✓	✓
Pepper, jalapeño		✓	✓	✓
Peas	✓			✓

Herbs that have been attempted in Growing Towers

Herbs	Direct seeded	Transplanted	Side of Tower	Top of Tower
Cilantro	✓	✓[P]	✓	✓
Oregano		✓[P]	✓	✓
Dill	✓	✓[P]	✓	✓
Basil		✓	✓	✓
Parsley		✓	✓	✓
Chives		✓[P]	✓	✓
Catnip		✓	✓	✓

[P] Perennial, will re-seed if planted on top of the Growing Tower.

Flowers that have been attempted in Growing Towers

Flowers	Direct seeded	Transplanted	Side of Tower	Top of Tower
Nasturtium		✓	✓	✓
Zinnia		✓	✓	✓
Marigold		✓	✓	✓
Sunflower	✓	✓	✓	✓
Violet		✓	✓	✓
Pansy		✓	✓	✓

1. Before transplanting into the side of a Growing Tower, cut squares out of the black plastic. Space the cuts based on the size of the plant at maturity. Stagger the cut squares vertically on the Growing Tower so that one plant will not grow directly above another.

2. Squares can be cut using a knife but this will leave the plastic frayed; however, a small handheld propane blow torch will quickly melt the plastic and prevent fraying in the future.

3. Create a hole for the transplant by driving the tip of a wooden stake downward about 4" into the soil column where the black plastic was cut and then insert the transplant into the hole.

4. Apply a small amount of pressure on the root ball of the transplant to anchor it in place. Lightly water the roots of the transplants after all have been planted.

It should be noted that plants often succumb to transplant damage in any situation, including transplanting into Growing Towers. After transplanting, plants will appear limp and drooping. This condition will last a day or two until the roots take hold but during this time the soil should be kept moist. Within a week, all transplants should appear to be healthy and growing vertically.

There is greater versatility with planting on top of a Growing Tower. For instance, root crops such as carrots and radishes can be direct seeded on top but could not be transplanted on the sides because it would be too difficult to harvest. Tall-growing plants such as sunflowers can be grown on top as well. Tomato cages can be installed on top of Growing Towers to support tomato growth and plants that prefer to climb such as peas and beans.

The number of plants that can be grown in Growing Towers will vary depending on the size of the Growing Tower and the type of plant. Naturally, the larger the plant is at maturity, the fewer the number of plants that can grow optimally in a Growing Tower. For instance, a 4-foot-tall, 2½-foot diameter Growing Tower could support four to six tomato plants on the sides while the same Growing Tower could support nearly 40 basil plants.

For two growing seasons, Rodale Institute documented plant production in Growing Towers. Side-by-side comparisons of Growing Towers and standard box plots show that plant production is comparable between the two systems, assuming irrigation challenges with Growing Towers are overcome (see page 16). Kale, Swiss chard, and most herbs tended to be the most productive plants overall to grow in Growing Towers. As mentioned previously, tomato and sometimes pepper plants require additional maintenance such as trellising to support growth, but afterwards, fruit production will be steady.

A number of annual flowers were tested in Growing Towers. Most flowers did quite well; however, flowers with longer stems such as sunflowers or cosmos grew well but also required additional support. All plants grown on the top of Growing Towers performed similarly compared to those grown in the ground.

6 OVERCOMING CHALLENGES

IRRIGATION

All plants require water for growth and reproduction, especially those grown for food production. When using Growing Towers it is challenging to provide water for plants near the bottom of the Growing Tower because water will not move as easily through the deep soil column. Therefore, Rodale Institute has designed a number of techniques to aid irrigation for Growing Towers.

5-Gallon Bucket

- Drill several holes in the bottom of a 5-gallon bucket near the periphery and one or two rows of holes in the sides.
- Submerge the perforated 5-gallon bucket into the top of a Growing Tower, leaving a few inches above the soil level.
- Fill the bucket with water and, over time, the water will percolate into the lower areas of the Growing Tower.

Soaker Hose

- Coil a soaker hose through a Growing Tower while filling with soil.
- After installation, attach a garden hose to the soaker hose and let it run for 10 to 20 minutes daily or as needed.
- A 50-foot soaker hose can be installed into two Growing Towers. In this case, install the hose in the Growing Towers so that the ends are on the top of the Growing Tower. That way, the bridge between the two Growing Towers will not travel from the top of one Growing Tower to the other, but will cross along the soil surface.

Vertical PVC

- Obtain 1- or 2-inch-diameter PVC piping and cut into lengths about 6 inches less than the height of the Growing Tower.
- Cap one end of the pipe using a rubber stopper. Drill several holes into the piping with a greater abundance of holes near the capped end.
- Use a rubber mallet to drive the pipe vertically, capped end first, through the Growing Tower until approximately 2 inches of the pipe is remaining above the top of the Growing Tower.
- Insert several PVC pipes along the wall of the Growing Tower while maintaining approximately 4- to 6-inch distance from the wall.
- After installation, use a garden hose to fill the pipes with water.
- This works best soon after filling the Growing Tower before the soil becomes too compacted.

Horizontal PVC

- Obtain 1-inch-diameter PVC piping and cut into several 12-inch lengths.
- Cap one end of each pipe using a rubber stopper.
- Drill several holes along one side of each pipe and then insert the pipes at a downward angle, capped end first, through the black plastic and into the sides of the Growing Tower.
- Stagger rows of pipes and insert them at a distance far enough from the plant that will permit access with a garden hose.
- Fill each pipe with water when it is time for watering.

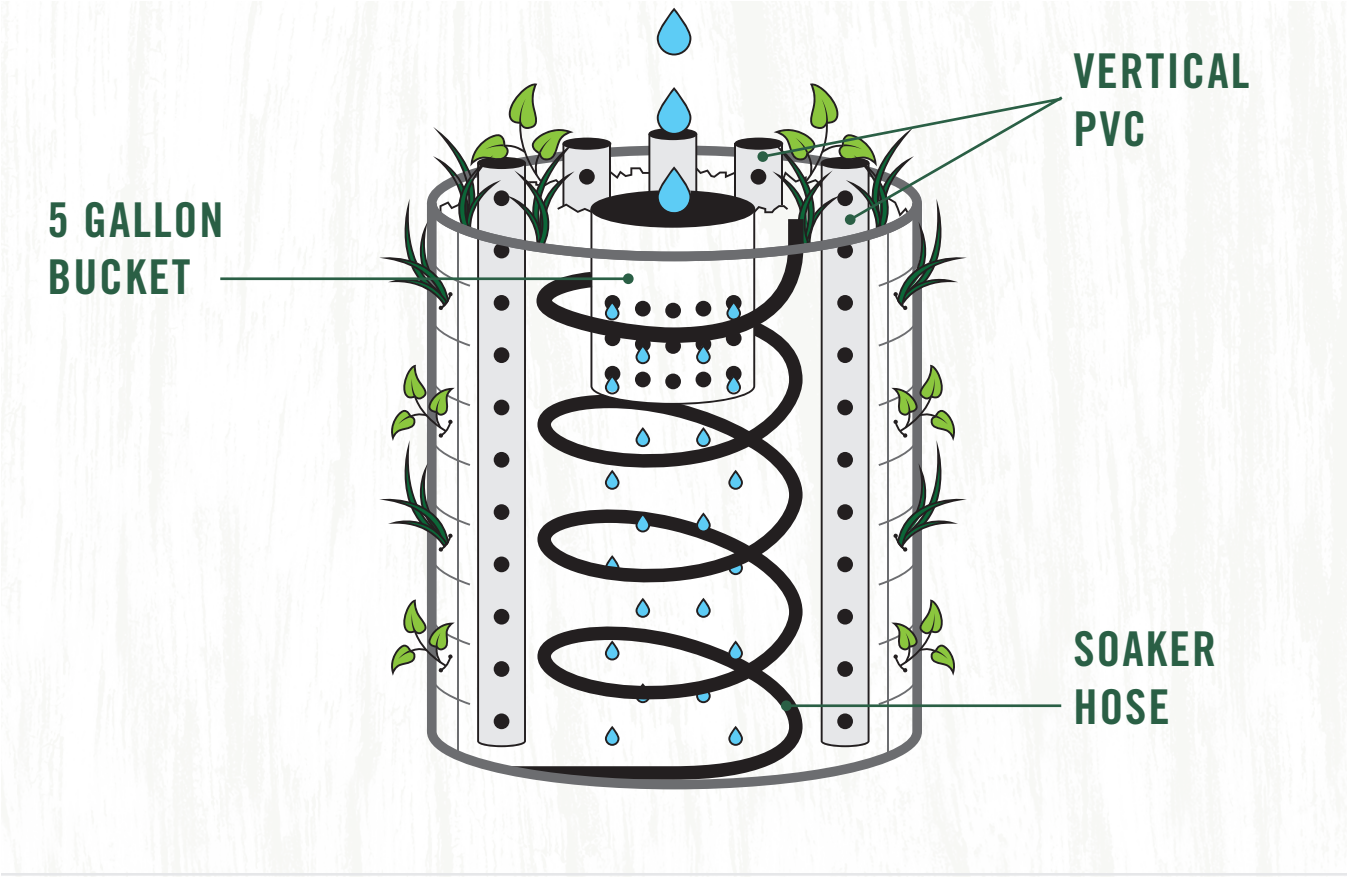
Build a Moat

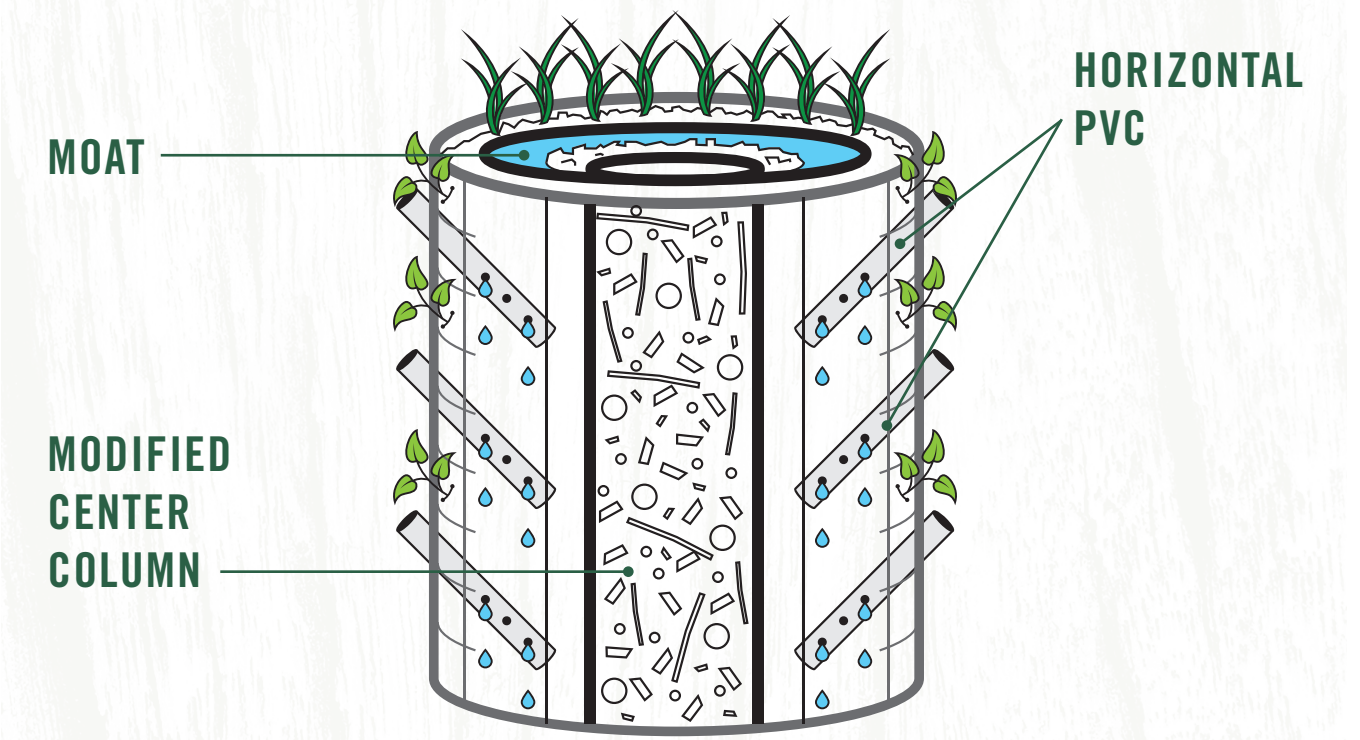
- Mound soil on the top along the sides of the Growing Tower and build another mound of soil near the center of the top.
- This essentially creates a moat on top of the Growing Tower and will allow water to penetrate into the soil column before running over the sides.

Modify the Center Column

- Modifying the soil media to increase water infiltration will improve irrigation for plants growing near the bottom of the Growing Tower.
- This will need to be completed while the Growing Tower is being built. Materials such as sand, gravel, wood chips, and straw will improve water infiltration.
- While filling the Growing Tower with soil, add one or more of the materials previously mentioned to the center of the column and fill the area around the modified center column with soil as usual.
- The diameter of the center column will vary depending on the overall diameter of the Growing Tower, but it's best to leave 6" to 8" of soil along the periphery of the Growing Tower for root growth.
- Continue to fill the Growing Tower, adding modified media to the center and then soil along the sides.
- Repeat until the Growing Tower is filled.
- Once the Growing Tower is filled and plants are growing, water the center column to allow water to flow readily to the roots of plants growing near the bottom.

Irrigation Techniques for Growing Towers





Growing Towers above show a variety of irrigation techniques and each technique will increase water infiltration into the soil column.

SOIL COMPACTION

Growing Towers will inevitably experience soil compaction with compaction increasing as the height of the Growing Tower increases. Soil compaction should not cause a problem during the first year of production, but it will be noticed when transplanting during subsequent years, especially near the bottom of the Growing Tower. Rodale Institute has explored a number of different solutions to alleviate soil compaction and those that showed promising results are discussed below.

Modify the Soil Media

Substituting inorganic materials such as sand, clay, silt, and larger rocks typically found in garden soil with ingredients from soilless media such as perlite and vermiculite will reduce the weight of the soil column. Adding 10% equal parts perlite and vermiculite to 50% compost-amended soil seemed to have reduced soil compaction in 3-foot Growing Towers. However, amending Growing Towers with greater than 10% soilless media could cause issues with excess moisture, which can be detrimental to root growth.

Modify the Center Column

Similar to modifying the center column as described in the irrigation section, building a Growing Tower with a center column containing straw, wood chips, or gravel could potentially reduce soil compaction experienced along the sides of the Growing Tower.

Rebuild the Growing Tower

If space is available, dismantling and rebuilding a Growing Tower every 2 to 3 years is likely to be the best solution for reducing soil compaction. While rebuilding, additional compost can be amended to the soil in order to provide valuable plant nutrients and beneficial microorganisms.

7 EXPANDING VERTICAL GARDENING OPTIONS

Rodale Institute's vertical gardening project began in 2015 and since then great progress has been made in developing Growing Tower technologies. However, there are so many other possibilities for adapting Growing Towers to fit the needs of urban residents and gardening enthusiasts. There are a few particularly interesting ideas for Growing Towers that haven't been attempted by Rodale Institute. For instance, build a Growing "Wall" by attaching welded wire to existing chain-link fencing. This structure would need to be reinforced with T-posts in order to maintain its wall-like feature.

Growing Towers can be used as teaching tools for elementary schools. These structures can be deployed on blacktops and soil surfaces and would provide a valuable opportunity for young children to learn the benefits of growing your own food. Furthermore, Growing Towers can be deployed at nursing homes to give residents who are less mobile or restricted to wheelchairs an opportunity to relive the joys of gardening. Harvested produce can then be used for cooking groups or other group activities. Growing Towers could also be used as a means to increase curb-appeal and beautification for business establishments throughout the city.

Rodale Institute kindly submits this booklet and other relevant vertical gardening documentation prepared by Rodale Institute to our sponsors, namely the USDA Natural Resources Conservation Service, Pennsylvania Conservation Innovation Grant program with the prospect of integrating these techniques and practices into other urban farming programs.

Rodale Institute offers two suggestions for integrating Growing Towers into current and future urban farming programs:

1. Include Growing Tower technologies in federal and state recommendations for promoting urban soil safety. For example, efforts to address issues with soil safety were previously described in the Urban Soil Safety section of this booklet. Rodale Institute encourages the Philadelphia Mayor's Food Policy Advisory Council Soil Safety Working Group and other similar agencies to incorporate Growing Tower technologies into their recommendations for implementing soil safety, especially when there is a risk of soil contaminants.
2. Recommend Growing Towers as options for food production in locations with limited space or else little to no access to native soil. There are numerous situations in both Allentown and Philadelphia where an apartment building is left vacant for an extended period of time, later condemned, and then eventually demolished. These city "pockets" are highly amenable to Growing Towers and city officials and community activists could include the vertical gardening practices demonstrated by Rodale Institute during community planning events.

In any case, the Growing Towers developed by Rodale Institute have demonstrated their use and effectiveness for growing a wide variety of plants in environments were space is limited and the potential for soil contamination exists.

ADDITIONAL RESOURCES

Rodale Institute, Kutztown, PA

U.S. Census Bureau

U.S. Environmental Protection Agency Brownfields Program

USDA Natural Resources Conservation Service

Penn State Extension

Soil Safety Working Group, Philadelphia Mayor's Food Policy Advisory Council

Pennsylvania Department of Environmental Protection

Agency for Toxic Substances and Disease Registry

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