Smart Gardening: An Introduction to Raised-Beds, Soils, Plant Nutrition, and Composting

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Introduction

This book was written for beginning gardeners looking to try raised beds for the first time and for those looking to broaden their knowledge regarding soil health, plant nutrition, and composting. Gardening efficiently will require knowledge, at least a little, in each of these areas. This book should give new gardeners a good foundation for how to maximize their efforts early on.

A raised-bed garden (RBG) is simply a garden situated above ground level. RBG methods allow gardening in difficult areas, provide better control over plant needs, and can boost overall productivity by overcoming limitations associated with in-ground gardening. When established, RBGs have the potential to be extremely fertile and easily sustainable even where native growing conditions are poor. This book contains advice to beginners regarding raised beds primarily from the standpoint of production of herb and vegetable crops at home. Following the methods outlined here will allow anyone to create a sustainable gardening system.

Beyond knowing how to create a raised-bed, it is important to understand the soil in which the plants will grow. Presented here is a brief discussion of soil, amendments, and pH. Understanding these basics will help you to create a healthy gardening environment. Furthermore, it is helpful to know a few things about how plants use nutrients to thrive. Often, failure in gardens can be attributed to a combination of problems stemming from issues in either the bed itself or in lack of care regarding one of the major needs of plants such as nutrition.

Lastly, a discussion of composting is presented. Composting allows a gardener to complete the circle by returning unused produce to the soil to enrich it for next season's crop. It is a wonderful way to reduce household and yard waste, provide nutrition to the plants, and improve the physical structure of the garden soil. Also presented is a method for stretching the value of compost by creating actively-aerated compost tea. Creating this liquid form of compost is an easy way to make your own fertilizer.

Chapter 1

Raised Bed Gardens

Raised bed gardening is a time-honored method of getting the garden to work more efficiently for you by raising it above ground level and filling it with the soil of your choice. This simple act of raising and filling a bed custom soil creates an environment for plants that is far more hospitable than an in-ground bed. This method is an easy, efficient alternative to traditional gardening.

1.1 Advantages

The benefits of RBGs versus traditional in-ground types (rows, hills, furrows) are numerous. The primary advantage of RBGs is that you will have total control over the condition of the soil contained in the raised portion of the garden. If you construct a raised bed yourself you will

also have the advantage of control over amending the soil directly below the raised bed. Soil in the raised beds will drain faster and warm up earlier than the ground soil.

The other advantages of RBGs are mostly about making life easier and your work more efficient. For one, when beds are raised, back strain is reduced during weeding, harvesting, or general maintenance activities. This is something you may not think about a lot, but once the beds are built, it's something you will notice and something for which you will be thankful. Yard chores are easier when beds are elevated. When weedeating, even if you are very careful, it is possible that you would damage a garden plant. With raised beds, this is much less likely and you can trim the lawn right up to the garden edge worry-free. If you construct a raised bed from wood or metal, it would be relatively easy to attach trellis supports directly to the bed frame material. If you are so inclined, a modular season-extending PVC hoop/plastic cover structure can be attached similarly to create a mini-greenhouse. In the same line of reasoning, this same structure is more easily removed from an RBG during hot summer months.

Advantages of RBGs over in-ground beds:

- Better control over soil content and conditions
- Easier access to plants for maintenance and harvesting
- Easier yard/lawn maintenance adjacent to the garden
- Easier trellis/hoop addition/modification
- Less soil disturbance (tilling, digging, etc.)
- Deeper loose soil for root-zone crops
- Increased drainage
- Earlier soil warming

1.2 Construction Notes

RBGs can be constructed out of any material strong enough to contain the soil, water, and plants. Rot-resistant wood, non-rusting metal, stone, rigid plastic, or a combination of any of these materials would be suitable. Each of the materials has its own advantages and disadvantages of course. Wood and plastic frames will usually be less expensive and easier to build. Cypress or cedar wood (both rot-resistant) is usually more expensive than pine or oak (neither being rot-resistant) but would be a better choice for an application where direct contact with moistened soil is made. Metal and stone frames will be more durable but will usually be more expensive and harder to work. A material that provides benefits of stone with relatively low cost is

cinder block. If the grey concrete look is not appealing to you, a cinder block bed can be easily faced with other materials to allow the bed to blend into the current landscape design. In this manner, the parts of the bed contacting the soil will be very durable and the exterior will be attractive.

There exist two main ways to create a raised bed. One way is to construct a frame and fill it with soil. The other way involves purchasing a large container and filling that with soil. The major difference in the two raised bed styles is that one is completely open to the ground below and allows full root penetration into the soil below the bottom of the bed. With purchased containers, the bottom is not usually open, reducing drainage. For sealed-bottom containers, it is recommended that drainage holes be added to prevent hypoxia, a low-oxygen condition at the root zone caused by excess water. Most garden plants will not tolerate overly wet roots for long periods of time. Container options are many, but some good ones include very large plastic tubs, galvanized or plastic stock tanks, or even large tractor tires.

Before you construct your RBG, consider the location with respect to the sun. If you live in Earth's northern hemisphere, you will receive more light over the course of the year from the South. If you want to take advantage of this, position the garden bed in a place where it will be exposed to the southern light entering your yard. Also consider the heights of your plants. If you were to position taller plants like corn on the south side of your garden, they would shade the plants behind them. Therefore, to

utilize light most efficiently, position your taller plants on the north side of the bed, and shorter plants toward the southern side. If you are considering the use of a trellis for beans or similar climbing plants, place it on the north side of the bed. If you live in the southern hemisphere, the directions will be reversed. Figure 1.1 shows how placing taller plants away from the dominant sun direction and shorter plants nearer to the sun's dominant direction protects short plants from excess shading.

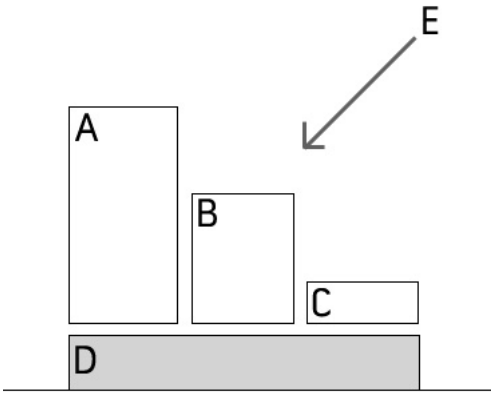

Figure 1.1: Raised Bed Garden Solar Alignment. A: Tall Plant Zone, B: Medium-height Plant Zone, C: Short Plant Zone, D: Raised Bed Frame, E: Dominant Sun Direction

If you prefer to construct your own bed, find a suitable location on flat ground and first remove any grass or other ground-covering plants. Under this grass layer you should mix 2-3" of compost into the soil about a foot down or so with a shovel or tiller. The goal is to create a soil environment that is loosened at a deeper level than it appears. Consider this construction method to be similar to building a house with a basement. The compost addition is a recommended step for new bed construction on any soil type but especially so for those soils rich in clay or sand because compost will feed your soil and condition it for good plant growth. When the sub-bed ground is finished, place a frame around the area and fill the bed with good soil while continuing to mix into the native sub-bed soil as you go. Mixing the old and new soil will help to avoid a drastic change in soil conditions between the two layers. As you fill the bed, you may want to mix in some fertilizers to get your plants off to a good start. Apply fertilizers at the manufacturer's recommended rate. The bed is ready for planting now and should roughly resemble the bed cross section seen in Figure 1.2. Be sure to water everything in well.

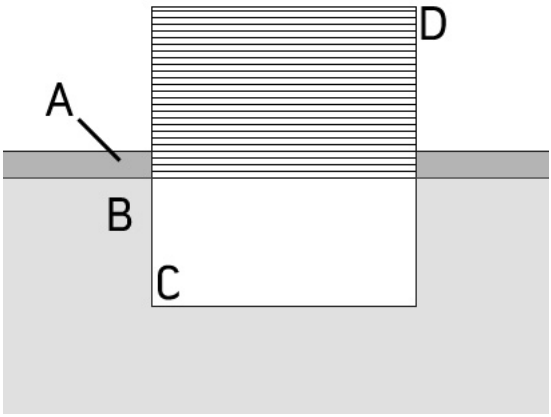

Figure 1.2: Open-bottom Raised Bed Garden Cross Section. A: Grass, B: Native Soil, C: Excavated Soil Region, D: Raised Bed Frame

Chapter 2

Soils and Amendments

Gardens thrive or fail based partly on the quality of the soil in which the plants are grown. The soil is the foundation for the garden and if it is inferior, your garden will be at best, an ongoing high-maintenance project, and at worst, a total failure with diseased and unproductive plants. Good soil should be a high-priority goal for any gardener and should be considered an investment in the success of the garden. If this goal is prioritized and worked toward diligently, the payoff will be well-worth the efforts invested.

Soil quality is a critical factor in the success of your garden. Poor or average soils can be made more hospitable to plant growth through the addition of soil amendments. These products improve the physical properties of soil such as water retention, drainage, and aeration, and add varying degrees of nutritive value as well. A well-amended soil

will provide a healthy home for plant roots and beneficial organisms and will provide the foundation for your gardening success.

2.1 Understanding Healthy Soil

If you want healthy soil, you need to know what exactly makes a soil healthy. It is useful to know that soil is not just plain old dirt. It is a complex substrate containing inorganic (never-living) material and organic (living or previously-living material). It is important to note that healthy soil is teeming with bacterial, fungal, and invertebrate life. Most of the organisms living in soil are either neutral or beneficial to your plants. Of course there are organisms that may infect or eat your plants but you need not worry about those things for now. You should also be aware that soils vary widely in the amounts of these inorganic and organic materials. The relative amounts of the soil components will lend varying characteristics to the soils and will determine what amendments you consider when trying to improve your garden bed. If you are unsure about your soil characteristics, contact your local extension agency to find out about getting your soil professionally tested. Soil tests are a highly-recommended way to find out what kind of soil you are working with before you try to improve it. These tests are usually performed for a nominal fee which makes them well-worth the upfront cost when you consider how much time and money

you may spend on unnecessary improvements.

2.2 Basic Soil Types

For the gardener, soils can be classified into three major types according to its texture defined by the dominant particle size. The three basic types are clay, silt and sand. A fourth type known as loam occurs when roughly equal proportions of the three basic particle sizes are found. Because of the variety of particle size and content, the three soil types will have a variety of physical and nutritive properties. A professional soil test will tell you what type of soil you have and will provide you with an accurate nutrition profile. Clay is composed of very small flat mineral-rich particles. As far as the gardener is concerned, is is a gummy soil type which is generally not very good for plant growth. If you have gumbo clay, usually found in the Southern US states, you are likely familiar with the sticky mess this type of soil can make after a heavy rain. Silt is a mineral product that is larger than clay particles but smaller than sand particles. Sand is composed of granular rock and mineral materials. These particles are large relative to clay. As a result, sandy soils do not retain water (or minerals) like clay. While easier to work in, sandy soils may suffer from a lack of nutrients. Because loam contains roughly equal proportions of the three basic soil types, it contains a rich supply of mineral nutrition, retains water well, drains efficiently, and breaks apart eas-

ily. Naturally-occurring loam soils tend to have higher amounts of organic matter in them as well. These properties make loam an ideal soil for plant growth. If you have a soil that leans heavily toward one of the three major types above, you can use soil amendments to create a more loam-like soil for your garden.

Soil structure describes how the particles clump together. Friability is the ability of the soil to crumble. A good loam would crumble under gentle hand pressure and would therefore be solid enough to hold plants in place yet yielding so that roots can grow easily. Clay, a dense soil type, does not crumble and is therefore not very friable. Sand is so loose it does not hold its shape very well and can erode easily. Both soil texture and structure are dependent on the interrelationship of particle size, type, and organic matter content. These factors in turn determine a soil's drainage and nutrient properties. Below is a table describing important soil factors.

Table 2.1: Soil Properties*

Property	Clay	Silt	Sand	Loam
Size[1]	$<2\mu m$	2-63μm	$63\mu m - 2mm$	Mixed
Shape	Flat	Round	Round	Mixed
Friability	L	M	H	M
Drainage	L	L	H	M
Water Retention	H	H	L	M
Nutrients	H	M	L	M
Nutrient Availability	L	M	L	M

*Low (L), Medium (M), High (H)

[1] ISO 14688: Geotechnical investigation and testing. Identification and classification of soil.

2.3 Amendments

Amendments are products used to improve the physical and chemical properties of soils. Fertilizers are technically amendments but are not commonly discussed as such. Organic fertilizers are discussed below. Depending on the product, an amendment will alter a soil's pH, drainage, mineral content, organic matter content, water retention, and friability. Consulting the results of a professional soil test will guide you toward which amendments you need for your soil. Amendments can be divided into two classes: organic and inorganic. Organic products are derived from living or once-living organisms. Inorganic products are

derived from sources like rock or minerals that were never living.

Organic amendments will decompose over time. As this process happens, the amendments will provide energy to microbes, release nutrients to the soil, and contribute to the soil structure in some way. Examples of recommended organic amendments include compost, humus, peat, and composted manure. Compost is decomposed organic matter generally created from plant matter or herbivorous animal waste (manure). Completely decomposed compost is known as humus. Compost is a great amendment for gardening because it is very good at improving soil structure and nutrition at the same time. Peat, another organic amendment, is partially decomposed vegetation found in bogs, wetlands, and similar areas. Its breakdown is prevented by local acidic or anaerobic conditions. Peat is naturally acidic and can retain a relatively large volume of water.

Inorganic amendments are synthetic or mineral in origin and will not decompose as readily as organic amendments. They will erode over a long period of time. Recommended amendments from this group include expanded shale, vermiculite, and perlite. Expanded shale is a product produced by heating gravel-sized shale particles to a point where they expand. This creates a porous rock that contains air spaces which can hold water in the soil. This product is used to break up clay soils. Vermiculite is a heat-expanded clay. It can be used to increase water retention or it can be used as a growing medium alone if watered

with a nutrient-rich solution. Perlite is heat-expanded volcanic glass. The heat causes water in the perlite to escape, creating bubbles within the now lightweight product. Perlite is used to break up and lighten soil and to aid in water retention.

2.4 Improving Soil

The amendments you will need to create your ideal soil will differ depending on the state of your native soil or the soil you use to fill your raised bed. The goal should be a soil that is fertile, containing all of the necessary nutrients for plant growth, and at a pH such that all the nutrients are available for uptake. The soil should be well-draining yet capable of holding water. The soil also should be friable so the roots can grow into it easily. If these conditions are met, your soil will be in good shape. No matter the initial condition though, every soil will change over time, settling in and losing nutrients to leaching. Therefore, every soil will need to be amended at some point, whether to create dramatic change, or simply for maintenance.

Amendments will differ for each soil type. If you have loam soil, consider yourself lucky. Your soil probably is relatively fertile and well-draining already, so you do not need to do much. Just keep a good thing going and you will be ok. If you till in an inch or so of compost or manure every year and keep your plants mulched, your garden should be in good shape. Clay soils tend to contain

many nutrients and retain water well. However, these soils may also drain slowly and some plants do not grow well in such environments. Clay soils benefit from the incorporation of organics like composted plant matter or manure to improve nutrition, drainage, and friability (the ability of the soil to crumble into small pieces). You may also consider a one-time application of expanded shale to improve drainage and aeration. It is recommended that you do not add straight sand to clay soils as this can create a very hard soil when dry. Sandy soils drain better than clay soils but do not hold nutrients very well as a result. Like clay soils, sandy gardening areas can be improved through the addition of organics such as composted plant material or manures. These materials will improve the water retention of the sandy soil and will add needed nutrition.

2.5 The Decomposers

Gardeners are highly concerned with plant growth and productivity. A gardener, however, should also be concerned with decomposition. Without good soil rich with decomposed organic matter, a garden will suffer. Therefore, it is wise to assist organisms responsible for decomposition, such as worms, bacteria, and fungi. These organisms that live in the soil break down organic and mineral components into chemical forms, making them available for uptake by plants. Worms eat organic matter and create waste that is high in nutrient value and also conditions

the soil. Encouraging the populations of these organisms is a good way to get your garden to work for itself with less maintenance on your part. This is most easily accomplished by increasing food sources by adding compost and/or a small layer of fresh vegetation waste tucked under some soil.

As far as most gardeners need be concerned, there are two major worm types: *Eisenia fetida*, or Red Wigglers, and Nightcrawlers (several species). Nightcrawlers like dark conditions and will burrow into the soil. Red Wigglers feed heavily on organic matter and will create beneficial castings. Think of the nightcrawlers as mini-tillers and Red Wigglers as mini-composters. If you have both in your garden, they will both contribute to the health of your plants by aerating and mixing the soil as well as generating castings that aid in improving plant nutrition. Nightcrawlers probably already live in your soil. You may see them on top of the ground or on sidewalks after a heavy rain. Red wigglers are often sold as fishing bait. If you would like to add some, buy some bait worms and add them to the garden.

If you are interested in using the worms to produce lots of castings for the garden, consider vermicomposting. Details can be found online or in other published sources. The basic method involves a stacked container system. Worms live in shredded newspaper or similar material to which fresh vegetable scraps are added from time to time. As they finish that source of food, they move up into another layer containing fresh food. After they finish that

layer, they move up into a third layer. At this time, the bottom layer is harvested for castings, cleaned, and placed on top of the currently occupied layer. This rotating system is available in several kit forms or you can build your own. Using red wigglers in a system like this is a good way to convert food scraps into usable garden compost. Additionally, the castings are a good source of compost for actively-aerated compost tea (discussed in this book).

2.6 Organic Fertilizers

According to the EPA, fertilizers recovered from organic materials benefit gardens because they:

- Improve physical soil properties, either directly or by activating living organisms in the soil.
- Provide better soil structure as a result of soil loosening and crumb stabilization.
- Increase water-holding capacity and soil aeration.
- Enhance uptake and utilization of plant nutrients, which leads to increased pathogen resistance and hardiness.
- Slow the leaching of nutrients from soil, resulting in extended availability through the growing season.

Background Document (Biosolids, Manure, and Fertilizers)
www.epa.gov/osw/conserve/tools/cpg/products/compost.htm

Chemical fertilizers, reduced to relatively simplistic formulations, offer quick, targeted action. This is highly useful if a specific remedy is required. One drawback is that chemical fertilizers are less-forgiving in terms of misapplication. If chemical fertilizers are used, it is recommended you use slow-release types and pay special attention to the manufacturer's directions. For general use, fertilizers derived from organic sources are preferable to chemical fertilizers unless there is a specific need to be met. Quick-acting and slow-release chemical fertilizers are efficient but they do not contribute to overall soil health because they do not contribute to the structure of the soil. Furthermore, organic-source fertilizers contain many more elements than the purer chemical fertilizers. This includes micronutrients which are vitally important. If you use an organic source Consider organic fertilizers an investment that does double duty: slow-release broad nutrition and soil health improvement.

There are many different organic fertilizers. Many of them are dried and ground up to form what is known as a meal. Here is some information about some of the more common ones:

Alfalfa meal: This is ground and dried alfalfa. Contains many nutrients needed for growth. Also contains triacontanol, a plant hormone responsible for growth. Decomposition of alfalfa meal can lead to soil warming. It is recommended that you do not add alfalfa meal directly to any planting hole but rather only scratch it into the sur-

face area around plantings.

Bat Guano: Another term for bat excrement composed of feces and urine. This product is mined from caves where bats live. You may find this offered with varying NPK ratios.

Blood Meal: Usually a bovine or porcine slaughterhouse by-product. Blood is high in nitrogen and if used excessively, can lead to burning.

Bone Meal: Another slaughterhouse by-product. Bone meal is high in phosphorus and contains calcium. Because of this calcium, a little bone meal around tomatoes and peppers can curb blossom end rot.

Corn Gluten Meal: A corn by-product that contains much nitrogen. Notable, this product is valued as a natural weed-and-feed. Used before weed seeds germinate, corn gluten meal prevents root formation. As it breaks down, the corn gluten feeds the already mature grass. Because of its adverse effects on germinating seeds, it is not advisable to use this product in a garden where you are planning to grow plants from seed.

Cottonseed Meal: This product is obtained after cotton seeds have been pressed to gather oil. It contains a fair amount of nitrogen as well as phosphorus and potassium.

Feather Meal: This is produced by essentially cooking feathers under pressure and then grinding them. The nitrogen source here is difficult to break down and thus serves as a very slow-release fertilizer.

Fish Emulsion: After fish have been processed for oil and fish meal (below), a liquid remains. Blended so the fat remains in suspension, a fish emulsion results. This product contains beneficial micronutrients.

Fish Meal: This is the dry part leftover from fish processing, ground to a meal form.

Kelp Meal: Generally, this is a ground meal made from dried *Ascophyllus nodosum*, a brown alga found in the ocean. This product is a good source of nitrogen, potassium, and micronutrients.

Poultry Manure: This is composted feces of chickens or turkeys usually. This type of manure makes a good all-around fertilizer.

Soybean Meal: The dry by-product of the soybean oil-extraction process. As with corn meal products, this product may inhibit seed viability so avoid using it when growing plants from seed. Otherwise, it is similar to cottonseed meal with regard to its NPK ratio (see below).

Wood Ash: When wood is burned, ash remains. The ash contains some of the micronutrients found in the wood. The exact composition of the ash varies directly with the type of wood burned. No matter the wood type, a major component of the ash is calcium carbonate which, when applied to soil, will raise the pH. If you are trying to keep your soil on the acid side of the pH scale, use wood ash sparingly.

Below is a table containing NPK values for a variety of these organic fertilizers. Due to the variable content of organic matter, these values are approximate. Actual NPK values will vary among manufacturers and products.

Table 2.2: NPK Values of Organic Fertilizers[1]

Fertilizer	N	P	K
Alfalfa Meal	2	1	2
Bat Guano, High N	10	3	1
Bat Guano, High P	3	10	1
Blood Meal	12	0	0
Bone Meal	3	15	0
Corn Gluten Meal	9	0	0
Cottonseed Meal	6	0.4	1.5
Feather Meal	7-12	0	0
Fish Emulsion	5	2	2
Fish Meal	10	6	2
Kelp Meal	1	0	2
Poultry Manure[2]	4	2	3
Soybean Meal	7	2	1
Wood Ash[2]	0	1-1.5	3-5

[1]cmg.colostate.edu/gardennotes/234.pdf

[2]Background Document (Biosolids, Manure, and Fertilizers)

[2]www.epa.gov/osw/conserve/tools/cpg/products/compost.htm

No one organic fertilizer is going to provide everything your garden needs. It is recommended you use them according to manufacturers's specifications alongside a regular yearly or bi-yearly application of compost. If you want to however, create a custom-blended formula using organic components, you can take advantages of the vari-

ous subtleties of the organic fertilizers.

A suggested custom-blend uses a recipe of common organic products. Simply combine one choice from each of the following three groups and you will have a balanced organic fertilizer ready for use in your garden. To use, apply a small amount around the base of each plant or mix some into the soil prior to planting.

- 2 parts Blood Meal *or* 3 parts Fish Meal (Nitrogen)
- 3 parts Bone Meal *or* 6 parts Rock Phosphate (Phosphorus)
- 1 part Kelp Meal *or* 6 parts Greensand (Potassium)

(Recipe from Great Garden Formulas, Benjamin, J. and Martin, D.L., Eds., Rodale Press, 1998)

2.7 Mulches

Mulching is the process of adding a layer of organic (e.g. chipped bark products, composts) or inorganic material (like plastic) to the top of the soil around plants. It is recommended you use organic mulches as they will break down and feed the soil over time. Also, these materials breathe better, let water into the bed, and will not look trashy as they disintegrate.

There are myriad options for mulching but three popular choices stand out. Pine bark mulch is the byproduct

of chipping or shredding the bark of pine trees. Pine straw is simply a collection of the fallen leaves of pine trees. Either of these is a good mulch and will have a slightly acidic quality that can benefit acid-loving plants or any plants in alkaline soils. Pine mulches tend to have a warm reddish tint. Hardwood mulches are derived from hardwood trees such as oak. These brown or grey mulches break down more slowly than soft woods like pine and are generally not as acidic. Compost is a great addition to any soil type but it also makes an excellent vegetable garden mulch for the reason that it is already well broken down and will not steal a lot of nutrition from plants as it settles into the soil. It will not last as long as some other mulches but this can be a good thing when you think about the benefits it brings to your garden as it breaks down completely. It is recommended that you apply a mix of well-decomposed compost as a great top dressing for any edible crop garden. Feed the soil and the soil will feed the plants.

2.8 Calculations

As a consumer, you can choose to purchase your soils and soil amendments in bags or in bulk. From a cost perspective, bulk purchases will likely be a better deal for you but you will need a truck, trailer, or an arrangement for delivery. Also, you will need a place to put the soil until you can move it to the garden. Bagged material is more convenient to move and will travel well in any vehicle. For

some amendments you will only need a small amount and thus bags will generally be your only option.

Basic applied math is necessary to calculate how much soil or mulch you will need to fill or cover a garden bed. To get started you will need to know a few things before you can run the calculations. First, you need to know the area (A) of your garden. If it is roughly square or rectangular, just multiply the length (l) and width (w). If it is circular, the area is equal to pi (about 3.14) times the radius squared. The radius is the distance from the center of the circle to one edge. If your garden is an unusual shape, it may be useful to mentally break the shape down into roughly rectangular sections for an estimated calculation.

Squares and Rectangles: $A = l \cdot w$
Circles: $A = \pi r^2$

Along with the area of the bed, you will need to know how the depth (D) in inches of the soil or amendment for which you are calculating. This is up to you but generally speaking, a fresh mulch/compost depth of 3" is good and a refresher depth would be about 1" or 2". For filling an empty raised bed, just get a measuring tape and see how deep the bed is from the ground to the top. Leave a couple of inches of headspace for mulch.

Once you have A and D figured out, you only need to know the volume (V) in cubic feet for each bag of soil or amendment. If you are buying in bulk, you do not need this last bit of information. Here are the formulae for bulk

purchasing and by-the-bag purchasing:

Bulk: Cubic Yards needed = $(A \cdot D)/324$
Bag: Bags needed = $(A \cdot D)/(12 \cdot V)$

Important conversions:
$1 yard^3 = 3' \cdot 3' \cdot 3'$ or $27 ft^3$.
$1 foot = 12 inches$.
To convert inches to feet, divide by 12.
To convert cubic feet to yards, divide by 27.

Here is a example showing how much mulch you need to cover a garden bed to demonstrate how the bulk formula was derived:

Area: $80' \cdot 4'$ or $320 ft^2$
Depth desired: 3"

Here we have the area (length and width in square feet) and the depth (aka height) in inches.

$$(80 \cdot 4) \cdot 3$$

To calculate, simplify the first multiplication and convert inches to feet by dividing by 12.

$$320 \cdot (\tfrac{3}{12})$$

Every measurement is now in feet so divide all of it by 27 to bring us to cubic yards.

$$\frac{320 \cdot (\frac{3}{12})}{27}$$

This can be rewritten more neatly but it leaves a complex fraction.

$$\frac{\frac{320 \cdot 3}{12}}{27}$$

Using the rule that any fraction is equal to the numerator times the reciprocal of the denominator, we can rewrite this as the multiplication of two fractions.

$$\frac{320 \cdot 3}{12} \cdot \frac{1}{27}$$

When multiplying two fractions, simply multiply the two numerators and multiply the two denominators, then simplify. This leaves:

$$\frac{320 \cdot 3 \cdot 1}{12 \cdot 27} \text{ or } \frac{320 \cdot 3}{324}$$

Solved, this yields 2.96 yards. Based on this calculation, you would need to buy 3 yards.

The bag formula, which calculates how many bags you need instead of how many yards you need, simply avoids this last simplification so you can substitute whatever volume is in the bag you are purchasing. Assuming 2 ft^3 per bag, this leaves the formula:

$$\frac{320 \cdot 3}{12 \cdot 2}$$

Solved, this formula yields 40 bags at 2 ft^3 per bag.

Chapter 3

Better Plant Performance

3.1 Plant Needs

Generally speaking, plants need soil, water, light, carbon dioxide, and nutrients. In order to let your plants do their best, you should understand the basic nutritional needs of plants. Different plants will require varying amounts of macro- and micronutrients to thrive and part of learning to maximize plant performance is understanding these needs and how to meet them. The need for macronutrients and micronutrients is generally met by roots feeding from the substrate. In a raised bed, with control over soil, amendments, and fertilizers, it is relatively easy to design and execute a plan for optimal soil health.

3.2 Nutrients

In his book entitled Mineral Nutrition of Plants, Principles and Perspectives (1972), Emanuel Epstein described elements necessary for plant growth. These elements are used in varying amounts by plants and are thus grouped according to their usage. Some important nutrients are non-mineral in origin. This group includes Carbon (C), Hydrogen (H), and Oxygen(O). These are the basic building blocks of life. Plants take carbon in from the air and both hydrogen and oxygen from air and water.

Mineral-origin nutrients that plants use in great quantity are called primary and secondary macronutrients. The primary macronutrient group includes Nitrogen (N), Phosphorus (P), Potassium (K). The secondary macronutrient group includes Calcium (Ca), Magnesium (Mg), and Sulfur (S). Because these nutrients are used in large quantities, they will need replacing more often and so are the primary constituents of popular fertilizers. Fertilizers are usually branded with a three-number ratio representing the available N, P, and K. Percentages of other important nutrients are usually listed on the label less conspicuously.

Micronutrients are those elements used in small amounts by plants. This is not to say they are unimportant, just that plants do not need much of them to live. This group includes Boron (B), Copper (Cu), Iron (Fe), Chlorine (Cl), Manganese (Mn), Zinc (Zn), and Molybdenum (Mo). You may see these referred to as trace elements. Some sources add Silicon (Si), Nickel (Ni), Selenium (Se), Sodium (Na),

Cobalt (Co), and Vanadium (V) to this list.

Each of these elements is used in a wide array of activities within the plant for structural and biochemical processes. Problems usually arise when a garden is deficient in one or more of these nutrients. Commonly, excessive watering leads to leaching of nutrients and subsequent deficiency. This is very common in potted plants. A regular fertilization schedule can combat nutrient deficiencies as can regular application of compost. Ask your local nursery for advice on and products for correcting specific nutrient deficiencies. Be careful when correcting deficiencies with fast-acting fertilizers as this can lead to burning, a condition where a high concentration of fertilizer is applied. Burning will result in yellowing and subsequent browning (and death) of leaves and possible whole plants. Organic-source fertilizers are less likely to burn. Be sure to follow manufacturers' recommendations for any fertilizer application. Below is a table listing a few nutrients and some side effects of deficiency in that nutrient.

Table 3.1: Nutrient Deficiency Symptoms*

Nutrient	Deficiency Symptom
Nitrogen	Yellow leaves, light green plant
Phosphorus	Burned leaf tips, dark older leaves
Potassium	Wilted older leaves, yellowing leaf bases
Sulfur	Yellow young leaves
Calcium	Distorted new leaves, blossom end rot
Magnesium	Yellowing older leaf margins
Iron	Yellowing between veins
Manganese	Yellowing between veins, distorted growth
Boron	Dying buds
Copper	Dark leaves, stunted growth
Zinc	Distorted leaves, yellowing between veins
Molybdenum	Yellowing older leaves, light green plant

*Adapted from The University of Arizona Extension Service, AZ-1106, 5/99

3.3 pH

The amount of free hydrogen ions in your soil determines the acidity or basicity of your soil. This level is known as the pH and is defined on a scale from 1 to 14. Low numbers indicate an acidic solution while high numbers indicate a basic solution. A pH of 7 is considered neutral. The pH of your soil is very important because pH determines the availability of nutrients for your plants. Because of the

chemistry of the soil and the nutrients themselves, some nutrients are held tightly by the soil at certain pH levels which limits their availability for your plants. Even if the nutrients are present in the soil, if they are not available, they cannot be used and cannot help your plants. It is therefore important to be aware of your soil pH so that you can control it and correct it to an acceptable range if it is negatively impacting your garden's health. If you prefer the *laissez-faire* approach, your garden beds will eventually fall in line to acceptable pH levels with regular additions of healthy compost but it might take more time than with active management on your part.

Correcting the pH of your garden soil is a gradual process. It is usually accomplished with slow-acting material such as lime or sulfur. Lime, aka calcium carbonate, raises pH. If you have overly acidic soil or plants that like alkaline soil, this can be used. Some fruiting plants like tomatoes can suffer from calcium deficiency leading to disease like blossom-end rot. Adding lime locally to each plant can counteract this and can prevent this specific disease. Sulfur is often used as a soil acidifier and is available in several forms, often with iron (e.g. iron sulfate). This type of product simultaneously corrects iron deficiency (common in basic soils) and acidifies the soil to make the iron more available. Other sulfur products are available without the iron if that is preferred.

Below is a table demonstrating major nutrient availabilities at varying pH levels. Notice the sweet spot around pH 6 where every nutrient is generally available in good

amounts. Not every plant type will prefer this lower pH but good nutrient availability at this pH will ensure better health for a broad range of plant types. If your garden pH is much higher than 6, consider some type of soil acidifier as an amendment. Some plants, like azalea, camellia, gardenia, and blueberry prefer a low pH. Growing these plants may be more difficult in pH ranges above neutral.

Table 3.2: Nutrient availabilities at various pH levels*

	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9
Nitrogen	L	M	H	H	H	H	H	H	H	M	L
Phosphorus	L	M	H	H	H	M	L	L	L	L	M
Potassium	L	M	H	H	H	H	H	H	M	L	L
Sulfur	L	L	M	H	H	H	H	H	H	H	H
Calcium	L	M	H	H	H	H	H	H	H	H	H
Magnesium	M	H	H	H	H	H	H	M	L	L	M
Iron	L	M	H	H	H	H	H	M	M	L	L
Manganese	H	H	H	H	M	L	L	L	L	M	H
Boron	L	M	H	H	H	M	L	L	L	M	H
Copper	L	M	M	H	H	M	M	M	M	M	M
Zinc	M	H	H	H	M	M	M	L	L	L	L
Molybdenum	L	M	M	H	H	H	H	H	H	H	H

*Low (L), Medium (M), High (H)

Adapted from University of Minnesota Extension Service, BU-01731, Revised 2004

3.4 Watering

Plants are essentially solar-powered water pumps and need a constant supply of water to survive. In general, as plants grow, they give off water vapor through their leaves and take up new water through their roots. Some plants are better than others at retaining their water supply within their tissues and do not need frequent watering. Others, especially those that produce fruits, will need regular watering. At the opposite extreme, some plants are quite happy to sit in flooded areas or ponds with no detrimental effects. No matter the types of plants you grow, it is important to understand how to water your plants. This requires knowledge about your plants' specific needs, your soil, and your weather conditions. For this discussion, the plants are assumed to be regular garden varieties grown in a raised bed, not succulents (drought-tolerant) or aquatic (flood-tolerant) types.

An ideal garden soil will be evenly moist around the entire root zone, not soggy or dry. To maintain this condition, you must consider several factors that affect how often plants need to be watered and how much water they need. By understanding these factors, you will develop a good sense of how to water your garden.

One factor involved in watering is the soil type. If you have a soil that drains well, this is good, as excess water can leave the root zone freely. You may find that you will need to water more frequently if you have a sharp-draining soil. If you have a slow-draining soil, your garden may be

prone to wet soil conditions and adverse effects which arise from this state. A good method to monitor the level of water in your soil is to simply stick your finger into the ground and see how wet it is at finger tip depth. It sound simple but many people fail to check this. Before watering, simply check the soil to see if it needs additional water or not. Over-watering can lead to low oxygen levels around the roots and can essentially drown a plant. Over-watering also leaches nutrients from the soil at a higher rate than if correct watering methods are used. Under-watering a plant deprives plants of a basic need and dehydrates them. Yellow leaves can be a sign of over-watering while brown leaves can be a sign of under-watering.

Another factor involved in watering is weather. During times of drought, high wind, excessive heat, or heavy rainfall, watering needs change. Your watering program will need to be flexible to adapt. If you rely on an automated sprinkler or other irrigation system to take care of watering, you may need to change settings to respond to varying environmental conditions.

A third factor in watering is plant size and root zone depth. Large plants generally need more water than small plants. Again, this seems obvious when you think about it but it is a common problem to apply water at the same rate to all plants. If you water only with a sprinkler system, you may be guilty of incorrectly assuming that all your watering needs are met with a programmed watering schedule. If you have little plants like seedlings, you will not need to apply much water. Established trees and

other large plants will benefit from adding many gallons of water at a very slow rate so that the water can soak deeply into the soil and not run off the surface.

In order to maximize watering effectiveness, you should consider the time of day when you water. Early mornings are recommended as the wind is usually calm and the temperatures are cool. Wind and heat increase evaporation leaving less water for the plants. By watering in the morning, you give plants the best opportunity to use the water and any excess will be gone before evening. Excess water remaining overnight may encourage unwanted fungal growth on your plants.

Finally, consider the season. Warmer spring and summer months will require more frequent watering. Cooler fall and winter months will require less frequent or even no watering, depending on the plants.

A note on trees and large plants:

For most garden plants, watering with a sprinkler for 15-20 minutes is sufficient to provide enough water to reach the appropriate depth. For large trees however, it is difficult to gauge how much water to add. According to the Colorado State extension service[1] , a good formula for estimating water needs is 10 gallons of water per inch of trunk diameter for each watering. Measure the trunk diameter at knee-height. A young 2-inch diameter tree will

[1] www.coopext.colostate.edu/4dmg/Trees/caring.htm

thus need 20 gallons. If you assume a hose-output rate of approximately 2 gallons per minute, you should water 10 minutes. Even better, water at a slower rate for a longer period of time, say 20 minutes at 1 gallon per minute. This will give the water a better opportunity to really soak into the ground as opposed to draining across the surface of the ground. You may consider using a soaker hose as a way to slowly supply large amounts of water. Watering should be done around the tree drip line, the area on the ground directly under the outer branches. The drip line is where the majority of a tree's small feeder roots are located. Watering and fertilizing in this are will be more effective than in other locations such as near the trunk.

Chapter 4

Compost

Compost is a great amendment for improving soil structure but it is also great for adding nutritive value to the garden. As an organic source, it will breakdown slowly, releasing its valuable nutrients over time. Although you can purchase ready-made compost made from a variety of sources, starting your own compost pile is a rewarding way to recycle kitchen and yard waste and improve your garden. Done correctly, compost will not smell bad and can be produced in a month or two.

There are easy ways to create compost and there are less-easy ways. The easiest way is to just pile up kitchen scraps in a pile and wait about a year or two until the bottom of the heap is black and crumbly. The less easy ways involve monitoring contents, layers, moisture levels, aeration, and volume. None of this is difficult to manage and anyone with available space should consider compost-

ing to feed the garden and reduce waste. To create a good compost pile, you will need some space (a good 8'x4' area away from the house), a pitchfork or similar tool, possibly a tarp, and some kitchen and yard waste.

4.1 Composting Rules

Proper composting requires adherence to a few rules. Follow these rules and you should be on your way in no time. After a while, you should have a healthy amount of rich, dark, crumbly compost ready to add to the garden as an amendment or top dressing.

Rule 1: No animal by-products with the exception of eggshells. Animal by-products take a long time to break down, will make your compost stink, and will attract unnecessary attention from animals. Conversely, vegetable and mushroom by-products are perfect for composting. Think vegetable peelings, stuff you did not add to the salad, grass clippings, pine straw, fallen leaves, etc. Do not forget to add coffee and tea leftovers. Paper coffee filters and tea bags, along with shredded newspaper are fine too. Do *not* add any obviously diseased material (like that now-fuzzy tomato you left in the back of the fridge for too long).

Rule 2: Green, Brown, and Black. Layering fresh material (green), dead material (brown), and soil or leftover

compost (black) is an effective way to accelerate the breakdown process. You will not need to add lots of soil or old compost to keep a pile going but the microbes you add with black materials are going to speed things along.

Rule 3: Turn the pile every few weeks. Turning the pile with a pitchfork into a nearby location mixes all the layers and allows fresh air to reach material that was previously inaccessible. If you turn too frequently, the pile may dry out prematurely and may not decompose well. If you wait too long, it is not that big of a problem but decomposition will take longer. If you want compost more quickly, remember to turn the pile.

Rule 4: The compost pile should have a minimum volume somewhere around $64ft^3$. This is no hard-and-fast rule but there is a limit to how small the pile can be and still decompose efficiently. Decomposition in the core of the pile leads to heat generation, which in turn, speeds decomposition. To achieve this critical mass, shoot for a pile in the 4'x4'x4' range or a little larger. If you build a pile too large , it will be more difficult to turn and aerate.

Rule 5: Keep the pile from drying out completely. Ideally, the pile will have a moisture level like that of a damp sponge. If you are in for a few days of heavy downpours, you might consider putting a tarp over the pile. If you are in a drought, water the pile a little when you turn it. This will keep the decomposition process moving along.

Too much water will slow things down and make a bit of a mess.

4.2 Compost Tea

Compost is a great addition to the garden in its normal form but it can be transformed into a liquid tea to create a more immediately available fertilizer. As was discussed previously, compost is decomposed organic matter. As such, it is teeming with microbes responsible for the decomposition process. In addition to the rich nutrients and the friable organic matter, these microbes are a valuable commodity for gardening. The reason for this is that, when added to garden beds, they will continue to work to further break down existing organic materials, releasing the components for uptake by plants. Encouraging the growth of these beneficial microbes will prove beneficial to the garden. One especially good way to encourage their growth is through a specialized method of extending the power of your compost. The product of this method is called Actively-aerated compost tea (AACT).

The process of brewing AACT requires compost, water, a sugary food source for microbes, and an active source of oxygen. The process is not simply open to the air, it requires the injection of oxygen to the solution. Without this oxygen injection, you simply create compost leachate. A watery extract of compost, if added to a garden bed

soon after it is made, is not bad but it does not actively encourage the growth of beneficial microbes in a strictly aerobic environment. What you avoid by actively aerating the tea is the process of fermentation which occurs in the absence of oxygen. This fermentation process is usually associated with an aroma that you may not want in your living environment. With stink-free AACT, the nutrient-rich compost leachate is produced along with many beneficial microbes.

After brewing, the liquid (tea) and solid particles (sludge) need to be separated. This can be accomplished by pouring the solution through mesh cloth or some similar strainer. The tea can be used to drench the ground or as a foliar spray. Foliar spraying is an efficient fertilization method because leaves absorb nutrients, especially during early morning and late evening. If you choose to use this method of application, ensure the liquid is free of all solid material. You may need to run the liquid through a series of finer mesh to screen the smallest solids to ensure your sprayer does not become clogged. Early morning spraying is recommended to allow the excess liquid to evaporate during the day. Excess moisture on leaves at night can encourage disease.

For brewing AACT, you will need some basic equipment. A simple yet effective system includes:

- A plastic 5-gallon bucket
- A small non-submersible aquarium pump (for 40-60gal aquariums)
- Air stones (makes bubbles)
- Air line tubing
- Weights (metal hardware nuts are good)
- A gang valve (splits the air supply, controls airflow)
- Unsulphured molasses (food source)

The bucket can be found at any mega-store or hardware store. The pump, airstones, tubing, and gang valve can all be found at any large pet store or aquarium supply store. The molasses can be found at a grocery store. None of these components are exceedingly expensive. When you have gathered your materials, assemble them as in the diagram below. Elevate the pump above the bucket to prevent backflow of water into the pump should the power go out unexpectedly. Mount the gang valve on the side of the bucket. Your setup should resemble the one seen in Figure 4.1.

To get started, stir the compost slurry well, set the airstones at the bottom of the bucket, add 2-3 tablespoons of molasses, activate the pump and ensure that bubbles are being produced. Stir the slurry between 1 and 3 times a day and let the pump run for 24-48 hours. At the end of brewing, strain the liquid through mesh cloth to remove

the solids. The remaining solids may be added to the garden or returned to the compost pile. The liquid tea can be poured into the garden bed or sprayed onto the plant leaves in the early morning. It is recommended that you clean your tea brewer equipment with a light brushing and clean water immediately after use. Brewing AACT it is a good way to extend your compost supply, boosting the population of beneficial microbes in the garden, and creating a nutrient-rich fertilizer.

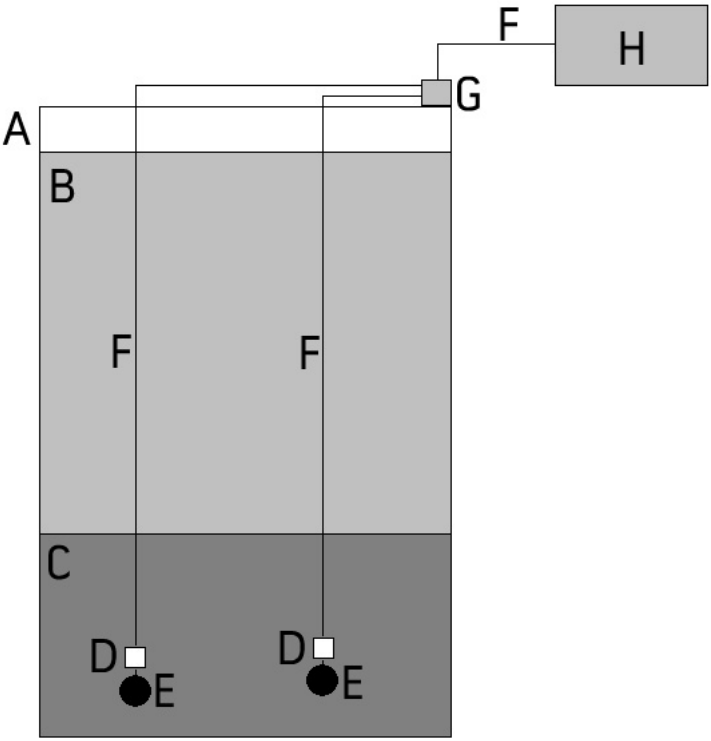

Figure 4.1: AACT Brewing System. A: Bucket, B: Water Level, C: Compost Level, D: Weight, E: Airstone, F: Airline, G: Gang Valve, H: Pump

Appendix A

Garden Notes

Experience is the best teacher. Use this area to record a few notes about your garden for future reference.