Sustainable and Urban Agriculture Series **Extension Bulletin 03-15**

Water Management for Raised-bed Gardens

Leonard Githinji, Ph.D.
Assistant Professor and Extension Specialist,
Sustainable and Urban Agriculture, Virginia State University
(804)524-5962; lgithinji@vsu.edu

1. Introduction

Raised-bed gardens are a form of gardens in which the soil is raised above the surrounding soil, sometimes enclosed by a frame generally made of wood, rock, or concrete blocks, and may be enriched with compost (Figure 1).

FIGURE 1: Raised-bed garden. *Source: Wilkinson (2013)*

Managing water in raised-bed gardens is a bit more challenging than in a traditional garden. Raised-bed gardens are often well drained and therefore the growing plants will rarely suffer any stress caused by overwatering. However, overwatering increases the amount of water loss through seepage from the base of the bed. Water deficit stress associated under-watering is a bigger challenge for raised beds since more plants are grown per square foot making the soil to dry out faster. Hence they require more frequent watering than traditional in-ground row plots. Failure to supply sufficient water, especially for deeper beds, can lead to delayed maturity and lower yields. To overcome the water-holding limitation inherent in raised beds, sufficient water should be supplied frequently and evenly. The amount and frequency of watering depend on the water holding capacity of your soil, weather conditions and water requirements of your plants.

2. Soil Water Holding Capacity

Apart from supplying nutrients to plants, one of the main functions of soil is to store moisture between rainfalls or irrigations. After irrigation or rainfall event, water is lost from the soil by the process of evaporation from the soil surface, transpiration by plants, and by deep percolation. If the water content becomes too low, plants become stressed. The capacity of the soil to provide storage and buffer the plants from dry spells is related to the soil water holding capacity. The availability of water for plant use depends not only on the amount of water present in a soil, but also on the energy status of that water. This energy status is referred to as matric potential, defined as that portion of the total water potential due to the attractive forces between water and soil solids and is always a negative value. When soil is saturated, all the pores are full of water. However, the loosely held water, referred to as gravitational water, will drain out of the soil subject to gravitational pull (Figure 2).

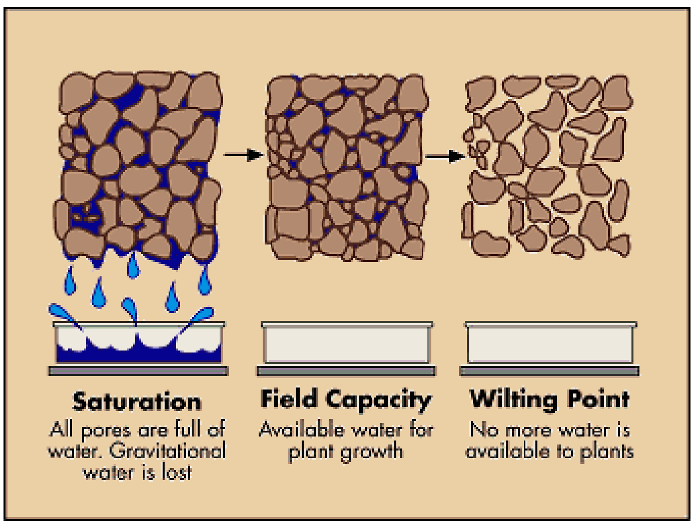

FIGURE 2: Water status in soil. *Source:* Blencowe et al. (1960)

The content of water that remains two to three days after the drainage of a previously saturated soil is referred to as the field capacity of the soil. At field capacity plants draw out water readily from the soil pores. As the soil dries out, plants will continue drawing water but at increasing difficulty until no more can be withdrawn, as the soil reaches the permanent wilting point, estimated to be the water content at -1,500 kPa of soil matric potential. The available water capacity (AWC) of a soil is defined as the difference between the water held at the field capacity and the permanent wilting point (Figure 3).

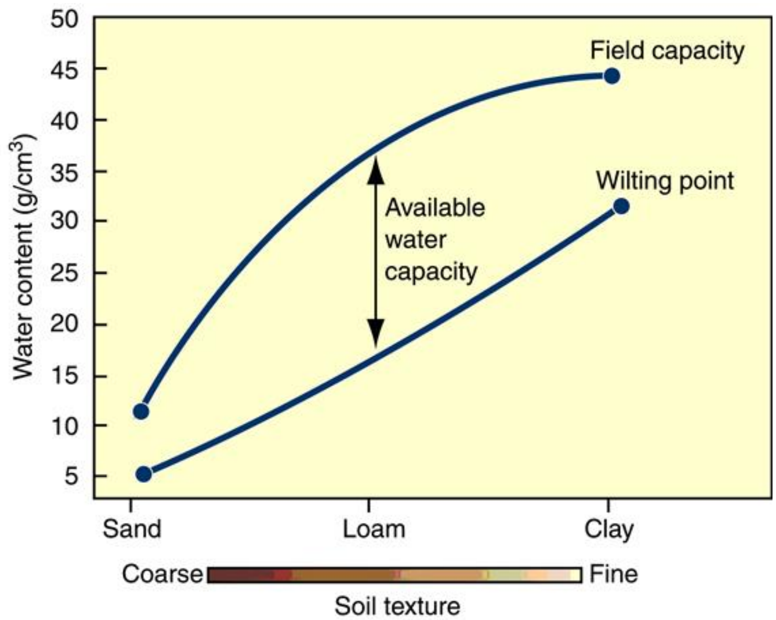

FIGURE 3: Available Water Capacity of soil. *Source: Blaskó Lajos (2008)*

Other terms with similar meanings are available water, plant available water, and water holding capacity. Water in the soil is readily available for plant use between the field capacity and halfway between the field capacity and the permanent wilting point. That point marks the beginning plan stress. The water holding capacity is dependent on soil composition, soil texture, and soil organic matter content.

2.1. Soil Composition

A typical soil is made up of 50% solids and 50% pores or void spade. The basic components of solid phase are minerals and organic matter while the pore space has water and/or air. The typical soil consists of approximately 45% mineral, 5% organic matter, 20-30% water, and 20-30% air (Figure 4). These percentages are only generalizations at best. In reality, the soil is very complex and dynamic. The broken line between water and air indicates that the proportions of these two components fluctuate depending on numerous factors such as water supply, cultivation practices, and/or soil type. Nonetheless, a nearly equal proportion of air and water is generally ideal for plant growth.

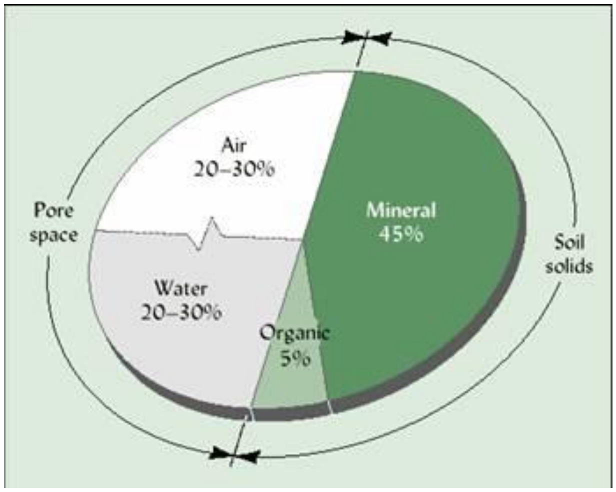

FIGURE 4: Approximate Composition of Soil. *Source:* Brady and Weil (2002)

2.2. Soil Texture

Soil texture refers to the relative fractions of sand, silt and clay. The USDA has defined twelve textural classes based on the relative composition of sand, silt, and clay (Figure 5).

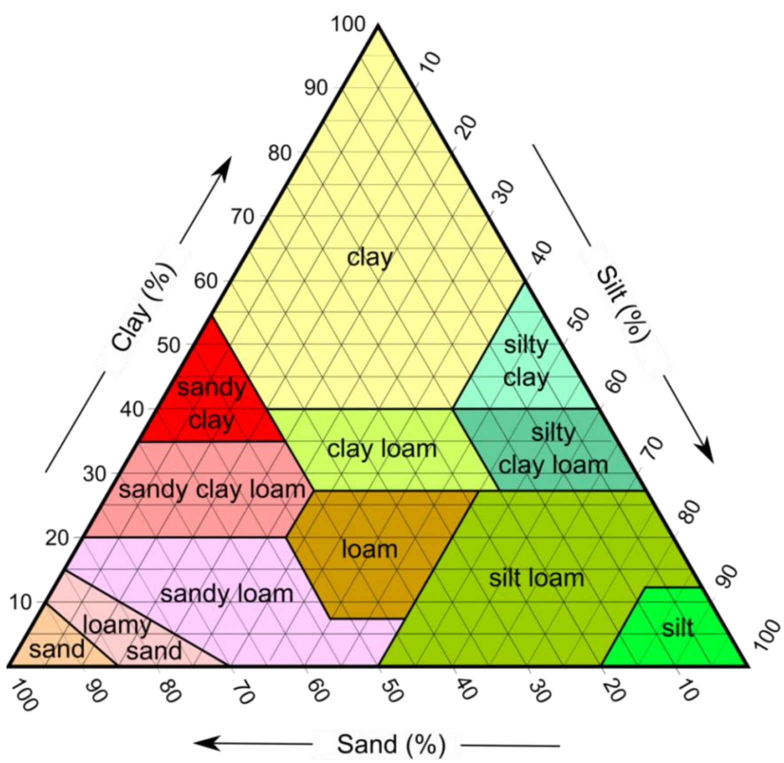

FIGURE 5: USDA Soil Textural Triangle. *Source: USDA (2011)*

These classes are clay, silty clay, silty clay loam, silt loam, silt, clay loam, loam, sandy clay, sandy clay loam, sandy loam, loamy sand, and sand. You can determine the textural class given any two of the sand, silt, or clay proportions. For example, a soil with 30% clay and 60% sand would be classified as a sandy clay loam, while a soil with 40% silt and 40% sand will be classified as a loam soil. A fine-textured soil has smaller but more numerous pores than a coarse-textured one, which has bigger particles but it has less porosity, or overall pore space. Water can be held tighter in small pores than in large ones, so fine soils tend to hold more water than coarse soils. Table 1 shows relative soil available water capacity as influenced by the soil texture. All other factors being equal, a sandy soil will dry and require irrigation sooner than a loam soil.

TABLE 1: Available water capacity as influenced by the soil. *Source: Ball (2001)*

Textural Class	Available Water Capacity (Inches/ Foot of Depth
Coarse sand	0.25-0.75
Fine sand	0.75-1.00
Loamy sand	1.10-1.20
Sandy loam	1.25-1.40
Fine sandy loam	1.50-2.00
Silt loam	2.00-2.50
Silty clay loam	1.80-2.00
Silty clay	1.50-1.70
Clay	1.20-1.50

2.2. Soil Organic Matter

Soil organic matter (SOM) is the organic matter component of soil, consisting of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms. SOM affects both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter include: soil structure; moisture holding capacity; diversity and activity of soil organisms; and nutrient availability.

Plant residues that cover the soil surface protect the soil from sealing and crusting by raindrop impact, thereby enhancing rainwater infiltration and reducing runoff. Surface infiltration depends on a number of factors including aggregation and stability, pore continuity and stability, the existence of cracks, and the soil surface condition. Increased organic matter contributes indirectly to soil porosity (via increased soil faunal activity). Fresh organic matter stimulates the activity of macrofauna such as earthworms, which create burrows lined with the glue-like secretion from their bodies and are intermittently filled with worm cast material. Increased levels of organic matter and associated soil fauna lead to greater pore space with the immediate result that water infiltrates more readily and can be held in the soil. The improved pore space is a consequence of the bioturbating activities of earthworms and other macro-organisms and channels left in the soil by decayed plant roots.

Organic matter also behaves somewhat like a sponge, with the ability to absorb and hold up to 90 percent of its weight in water. A great advantage of the water-holding capacity of organic matter is that the matter will release most of the water that it absorbs to plants. In contrast, clay holds great quantities of water, but much of it is unavailable to plants.

3. Available Water Capacity and Critical Moisture Stress

Crops have critical moisture periods when soil moisture stress can reduce yield significantly in an otherwise healthy crop (Table 2). Critical moisture period is not the only time in the life of the crop that moisture stress reduces yield, but the time when moisture stress will exert its greatest effect. Most vegetable crops are sensitive to drought during two periods: during harvest and 2-3 weeks before harvest. Leafy vegetables are planted at or near field capacity, and being shallow rooted, they benefit from frequent irrigation throughout the season. Leaf expansion relates closely to water availability; hence they are particularly sensitive to drought stress during the period between head formation and harvest. In addition, overwatering or irregular watering can result in burst heads for cabbage. Root and bulb crops have yield that depends on the production and translocation of food from the leaf to the root or bulb. The most sensitive stage of growth generally occurs as these storage organs enlarge. Water stress causes the formation of small, woody, and poorly flavored roots. Uneven irrigation can lead to misshapen or split roots and early bulbing in onions. Fruits and seeds vegetables are crops are most sensitive to drought stress at flowering and during fruit and seed development. Fruit set on these crops can be seriously reduced if water is limiting. An adequate supply of water can reduce the incidence of fruit cracking and blossom-end rot in tomatoes and peppers.

TABLE 2. Available water capacity, and suction and critical need stage for vegetables
(Modified from Sander, 1997 and Black et al., 2013)

Crop	Min. AWC[1] (cm^3/cm^3)	Min. Suction (centibars)	Critical water need stage
Asparagus	40	-7.0	Establishment and fern development
Bean, green	50	-4.5	Bloom and pod set
Bean, pinto	50	-4.5	Bloom and pod set
Beet, table	20	-3.4	Establishment and early growth
Broccoli	70	-4.5	Establishment and heading
Cabbage	70	-7.0	Uniform throughout growth
Cantaloupe	60	-20.0	Establishment vining to first net
Carrot	50	-2.5	Emergence through establishment
Cauliflower	60	-2.5	Establishment and 6 - 7 leaf stage
Celery	70	-3.4	Uniform throughout growth
Collards/kale	50	-4.5	Uniform throughout growth
Corn, sweet	50	-4.5	Establishment, tasselling and ear dev.
Cucumber	50	-4.5	Establishment, vining, fruit set
Eggplant	50	-4.5	bloom through fruit set
Garlic	70	-2.5	Rapid growth to maturity
Lettuce	60	-3.5	Establishment
Mustard green	70	-2.5	Uniform throughout growth
Okra	40	-7.0	Flowering
Onion	70	-2.5	Bulbing and bulb expansion
Pepper, bell	50	-4.5	Establishment, bloomset
Potato, irish	70	-3.5	After flowering
Pumpkin	40	-3.5	Bloom, fruit set and development
Radish	70	-2.5	Uniform throughout growth
Spinach	70	-4.5	Uniform throughout growth
Squash, sum.	70	-2.5	Fruit sizing
Squash, winter	40	-7.0	Fruit sizing
Sweetpotato	20	-20.0	First and last 40 days
Tomato	50	-4.5	Bloom through harvest
Turnip	50	-4.5	Root expansion
Watermelon	40	-20.0	Fruit expansion

[1] AWC (Available Water Capacity) is the water held between field capacity and permanent wilting point.

4. Irrigation Methods

Irrigation is the controlled application of water for to supply water requirements not satisfied by rainfall. There are basically four methods of irrigation, viz. Surface; Sprinkler; Drip/trickle; and Subsurface.

Surface Irrigation consists of a broad class of irrigation methods in which water is distributed over the soil surface by gravity flow. The irrigation water is introduced into level or graded furrows or basins, using siphons, gated pipe, or turnout structures, and is allowed to advance across the field. Surface irrigation is best suited to flat land slopes, and medium to fine textured soil types which promote the lateral spread of water down the furrow row or across the basin.

Sprinkler irrigation is a method of irrigation in which water is sprayed, or sprinkled through the air in rain like drops. The spray and sprinkling devices can be permanently set in place (solid set), temporarily set and then moved after a given amount of water has been applied (portable set or intermittent mechanical move), or they can be mounted on booms and pipelines that continuously travel across the land surface (wheel roll, linear move, center pivot).

Drip/trickle irrigation systems are methods of micro-irrigation wherein water is applied through emitters to the soil surface as drops or small streams. The discharge rate of the emitters is low so this irrigation method can be used on all soil types.

Subsurface irrigation consists of methods whereby irrigation water is applied below the soil surface. The specific type of irrigation method varies depending on the depth of the water table. When the water table is well below the surface, drip or trickle irrigation emission devices can be buried below the soil surface (usually within the plant root zone). Drip irrigation involves applying water directly to the root zone of plants by means of applicators such as orifices, emitters, porous tubing, or perforated pipe. It is operated under low pressure with the applicators being placed either on or below the surface of the ground. It is the most ideal application method for raised-bed gardens because it delivers a low-volume, steady supply of moisture in frequent doses.

References

Ball, J. 2001. Soil and Water Relationships. The Noble Foundation. http://www.noble.org/ag/soils/soilwaterrelationships/

Black, B., Hill, R. and Cardon, G. 2013. Irrigation. *In* Intermountain Commercial Tree Fruit Production Guide. A publication by Utah State University, Colorado State University, and University of Idaho. http://intermountainfruit.org/files/uploads/intermountainfruit2013.pdf

Blaskó Lajos (2008). Soil Science Digital Book. AMOP 4.2.5 http://www.tankonyvtar.hu/en/tartalom/tamop425/0032_talajtan/ch07s02.html

Blencowe, J.P.B., Moore S.D., Young G.J., Shearer R.C., Hagerstrom R., Conley W.M. and Potter J.S. 1960. U.S. Soil Department of Agriculture Bulletin 462. 1960.

Brady N. C. and Weil R. R. 2002. The Nature and Properties of Soils, 13th Edition. Prentice Hall, NJ.

Sanders, D.C. 1997. Vegetable Crop Irrigation. Horticulture Information Leaflet 33-E. North Carolina Cooperative Extension Service. http://content.ces.ncsu.edu/vegetable-crop- irrigation.pdf

USDA. 2011. http://commons.wikimedia.org/wiki/File%3ASoilTexture_USDA.png

Wilkinson, R. 2013. Vegetable Garden Plan. Under design, garden, vegetables. http://www.hipchickdigs.com/2013/02/vegetable-garden-plan/