MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #132

Plant Structures: Roots

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Roots are the beginning of the vascular system pipeline that moves water and minerals from the soil up through the plant body.

To function, roots must have adequate levels of soil oxygen. Soil compaction or waterlogged soil situations, which reduce soil oxygen levels, will kill roots and lead to a shallow root system.

The structure and growth habits of roots have a pronounced effect on:

- Size and vigor of the plants.
- Adaptation to certain soils.
- Response to cultural practices.

Because they are out of sight, roots are often out of mind. They are widely overlooked as to their significance in plant health. The majority of all plant problems start with soil/root problems.

Functions of Roots

- Anchor and support plants.
- Absorb and conduct water and minerals.
- Store products of photosynthesis (carbohydrates, sugars, proteins).
    - Winter survival of perennials.
- Horticultural uses.
    - Food and feed.
    - Propagation.
    - Soil erosion control.

Structure

Primary (young) root in cross section. [**Figure 1**]

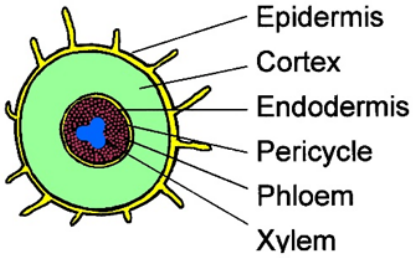

Figure 1. Cross section of a root.

Epidermis – The outer layer of cells.

Root hairs – Absorptive unicellular extensions of epidermal cells of a root. These tiny, hair-like structures function as the major site of water and mineral uptake. Root hairs are very delicate and subject to desiccation. Root hairs are easily destroyed in transplanting.
[**Figure 2**]

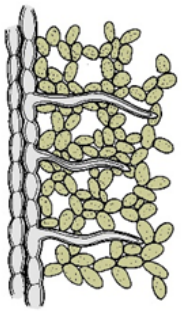

Figure 2. Root hairs are an extension of the epidermis.

Cortex – Primary tissues of a root bordered on the outside by the epidermis and on the inside by the endodermis. When roots begin thickening (secondary growth), the cortex and epidermis are gradually shed and replaced by the periderm.

Endodermis – A single layer of cells in a root that separates the cortex tissues from the pericycle. The endodermis includes the **Casparian Strip**, an impermeable layer that allows plants to control which substances can move from the cortex into the vascular system for transport to the rest of the plant.

Pericycle – A layer of parenchyma cells immediately inside the endodermis. Branch roots arise from the pericycle.

Vascular system

> **Phloem** tissue conducts products of photosynthesis from leaves throughout the plant including down to the roots.
>
> **Xylem** tissue conducts water and minerals from the roots up through the plant.

Root Meristems

[**Figure 3**]

Root Tip Meristem – Region of cell division that supports root elongation, found at the root tips just behind the root cap.

Root Cap – A thimble-shaped group of thick-walled cells at the root tip serves as a “hard hat” to push through soil. The root cap protects the tender meristem tissues.

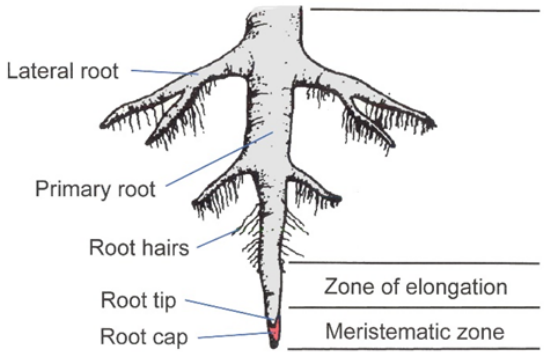

Figure 3. Lateral view of a root.

Vascular Cambium – The site of secondary root growth (root thickening). Vascular cambium develops in association with primary xylem and phloem and annually generates new vascular tissue in a ring shape, increasing the root girth and gradually crushing and sloughing off the pericycle, endodermis, cortex, and epidermis, replacing it with periderm.

Fibrous – Profusely branched roots that occupy a large volume of shallow soil around a plant's base (petunias, beans, peas). [**Figure 4**]

Taproot – Main, downward-growing root with limited branching, where soils permit (carrots, beets, radishes). [**Figure 4**]

Adventitious Roots – Generated in the ground system and arise at an "unexpected" place. For example, the buttress roots on corn and the short whitish bumps along a tomato stem are adventitious roots.

Aerial Roots – Arise from above-ground stem tissues. Aerial roots are common on ficus, philodendrons, pothos, and Christmas cactus.

Lateral Roots – The building blocks of the root system; branching roots that grow horizontally from the pericycle of the primary root.

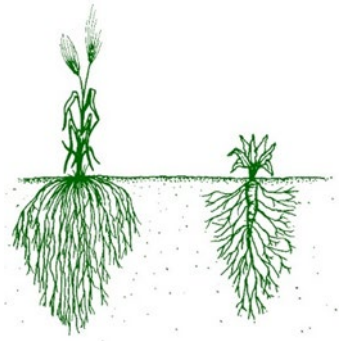

Figure 4. Root types.
Left: Fibrous root system of corn.
Right: Taproot system of carrot.

Sinker Roots – Make a sharp dive into deeper soils, wherever oxygen is available. Sinker roots are common on some tree species.

Storage or Tuberous Root – Enlarged roots that serve as storage organs (Canada thistle, morning glory, sweet potato, dahlia).

Depth and Spread

The depth and spread of roots are dependent on the inherent growth characteristics of the plant and the soil's texture and structure. Roots require adequate levels of soil oxygen, so growth habit will be determined by where oxygen is available in addition to inherent plant characteristics. [**Figure 5**]

In compacted soils, roots will be shallow, remaining near the surface where oxygen is available.

In droughty soils, the root system will often spread farther, mining a larger soil area for moisture and minerals.

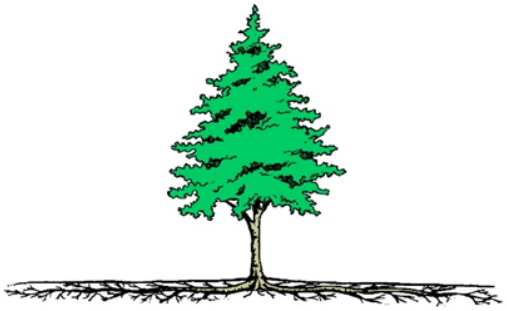

Figure 5. Typical rooting pattern of trees. Shallow and spreading.

It is difficult to predict root spread and depth. Under favorable growing conditions, the typical rooting of a tree includes:

- 90-95% of roots in the top thirty-six inches.
- 50% of roots in the top twelve inches.
- Extends two to three times tree's height or canopy (dripline) spread.

In compacted clayey soils, the typical root spread of trees includes:

- 90-95% of roots in the top twelve inches or less.
- 50% of roots in the top four inches.
- Potentially extends five or more times the tree's height or canopy (dripline) spread.

Some plants are genetically programmed to have very deep, spreading root systems (i.e., they are more tolerant of low soil oxygen levels). This growth habit is an environmental adaptation. Examples include bindweed and prairie grasses.

Soil type is a key factor in water penetration and root uptake. Where soil allows, the primary water extraction depth extends to:

- Flowers – eighteen to twenty-four inches.
- Turf – twenty-four inches.
- Vegetables – twenty-four inches.
- Shade trees – twenty-four to sixty inches.

Root Associations

Mycorrhizae are beneficial soil fungi that form mutualistic (mutually beneficial) associations with plants via roots. While the role of mycorrhizae is not fully understood, they function to expand the root's contact with the soil profile, enhancing water, and nutrient uptake. The same mycorrhizal partner can be associated with multiple trees, connecting multiple individuals. For additional information, refer to CMG GardenNotes #212, The Living Soil.

Rhizobium is a beneficial soil bacterium that forms a mutualistic relationship with plants, primarily those in the bean/pea family. These bacteria make atmospheric nitrogen available to plants. Rhizobium typically forms nodules on the roots of plants. These may be mistaken for insect injury or deformity. When alfalfa, a member of the bean/pea family, is left to mature then tilled into a field, it is considered "green manure" because the plant is rich in nitrogen due to the Rhizobium in the roots.

Natural Root Grafts are formed between roots of different trees, usually of the same species. Roots that come into contact with one another fuse at root hairs and can subsequently grow together by secondary growth, establishing a vascular connection between individuals. Large numbers of plants can become connected in this way; providing a mechanism for not only resources but pathogens and poisons to be shared widely.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

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