Tree Physiology and Growth

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Principal Parts of a Vascular Plant

Vegetative structures – leaves, stems, roots

Reproductive structures – flowers, fruits/cones, seeds

Growth is a cellular process that results in the increase in size and number of leaves, stems, and roots and the production of reproductive structures

http://extension.oregonstate.edu/mg/botany/external.html
• Basic structural and physiological units of plants
• Most plant reactions (growth, photosynthesis, respiration, etc) occur at the cellular level
Plant Tissues – Large organized groups of similar cells that work together to perform a specific function

i.e. Meristems, xylem, phloem, etc.
Plant Growth

• Growth occurs via meristematic tissues – cell division, elongation and differentiation

• Is influenced by genetics

• Is influenced by environment (water, light, temperature, nutrients, pests)

• Is influenced by plant hormones

• Growth activity can be manipulated by cultural practices (shearing, etc.)
Plant Growth and Development

Three major physiological functions drive growth and development

- Photosynthesis
- Respiration
- Transpiration
Function of Vegetative Structures

**Leaves** - absorb sunlight to manufacture plant sugars (photosynthesis) and provide energy (respiration) to produce proteins, etc. needed for cell growth

**Stems** – support, transport of materials (food, minerals, hormones, water, etc,) and storage of carbohydrates

**Roots** - absorb nutrients and water, anchor plant in soil, support stem, storage of carbohydrates, and produce hormones
Seedling Survival is Closely Related to Seedling Stem Caliper

Source: Bert Cregg, MSU; Adapted from South and Mexal (1984).
Root to Shoot Ratio and Height

Douglas-fir seedlings with a shoot/root ratio (S/R) of 0.8 had 25% greater survival than seedlings with a S/R greater than 1 on dry sites in the PNW.
Root Structure – 3 major zones

- Lateral root
- Primary root
- Root hair
- Root tip
- Root cap
- Zone of elongation
- Zone of maturation
- Meristematic zone
Uptake of Water and Nutrients by Roots

**Epidermis** – outermost layer where water and nutrient absorption occurs

**Root hairs** – increase surface area and absorption (short lived)

**Cortex** – movement of water from epidermis to vascular tissue

**Vascular tissue** – movement of water, nutrients, and carbohydrates throughout plant
Mycorrhizae – increase nutrient absorption

Mutualism

Ectomycorrhizal Root Tips

Plant Root

Fungus

Fixed Carbon

Increased Nutrients

Increased Water Uptake

Protection from Pathogens

Distribution of Root Systems

Generally limited to top 12” of soil

Affected by host, soil type, saturation and compaction
Roots Require Oxygen to Survive and Grow

Oxygen Requirements
- Root survival – need 3% $O_2$ in soil
- Apical meristem region requires 5 to 10% $O_2$
- New root formation $\geq$ 12% $O_2$

Soils and Oxygen Levels
- Undisturbed loam soil – 0 to 6” depth $\sim$ 20%
- Sandy soil – 15% at 5 feet
- Clay loam soil does not have enough oxygen to support root growth at 3 feet
- Compacted loam soil - 5% at 15 inches, roots will survive, but new roots would be stressed
## Effect of Soil Compaction on Monterey Pine Shoot and Root Growth

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<th>Soil bulk density (g/cm³)</th>
<th>Dry volume</th>
<th>Root volume (cm³)</th>
<th>Height (cm)</th>
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>bulk density = > compaction

Annual Shoot and Root Growth Patterns (Conifers in PNW)
Roots Require Oxygen to Survive and Grow

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Planting Stock Types

- Seedlings – bare root and plugs
- Transplants – bare root, plug + bare root, and plug + plug
- Rooted cuttings
- Grafted
Planting Stock Type
Container (plug) vs bare root
Planting Stock Type

Container (plug) vs bare root

- Out planting performance differences have been variable!
- In general, container seedlings tend to:
  - be less prone to stress during shipping and storage
  - be better on droughty or stressful sites
  - provide a wider window for planting
  - be more expensive for a given size
  - have more root problems
  - take longer for roots to come in contact with soil
  - increase the time for water movement from soil to seedling roots
Container Stock Root Structure
Plug Transplants are Becoming Increasingly Popular

Advantages include:

• rapid turnaround

• maximum control of growing environment during early stages of growth

• advantages of bare root production for the end customer – hardy seedlings that establish rapidly at the out planting site
Vascular System = plumbing

**Xylem** – conducts water and dissolved nutrients

**Phloem** – movement of carbohydrates, hormones, etc

**Cambium** – meristematic tissue
Balsam Fir Christmas Tree Stem

Cambium

Bark

Xylem

tracheids

fibers

parachama cells

Annual growth ring

Photo H.D. Grissino-Mayer http://web.utk.edu/~grissino/gallery.htm#Rings
Conifer Xylem

- Have “nonporous” wood consisting of tracheids, fibers and parenchyma cells
- Tracheids - hollow primitive cells (1 mm long) that have pits
- Fibers - thick walled, structural strength
- Parenchyma cells - produce vascular rays that provide for lateral movement of material across the stem and respond to wounds
Xylem and Phloem Tissues

Vascular Tissues

**Xylem**
- Conducts water and minerals from soil to all plant parts
- **Vessels**
  - Vessel: no end walls, pitted walls
  - Tracheids: perforated end walls, annular or helical thickenings
- **Fibers**
  - Heavy wall throughout

**Phloem**
- Conducts water and sugars from leaves to other parts (roots, stems, lateral or terminal buds, flowers, fruits)
- **Sieve Cells**
  - Endwall - sieve plate
  - Paired
- **Companion Cells**
  - Parenchyma
  - Fibers

http://koning.ecsu.ctstateu.edu

http://www.biologie.uni-hamburg.de/b-online/e06/06b.htm
Radial sections of *Abies pectinata* wood showing bordered pits on tracheids

Annual growth ring

← Pith ray

Photo Peter v. Sengbusch http://www.biologie.uni-hamburg.de/b-online/e06/abieshof.htm
Tree ring showing springwood (larger) and summerwood (smaller) cells

Photo Laboratory of Tree-Ring Research [http://web.utk.edu/~grissino/gallery.htm#Rings](http://web.utk.edu/~grissino/gallery.htm#Rings)
Douglas-fir Tree Rings

Photo © H.D. Grissino-Mayer http://web.utk.edu/~grissino/gallery.htm#Rings
Suppressed growth due to a forest fire that damaged the trees in 1685

Photo © H.D. Grissino-Mayer http://web.utk.edu/~grissino/gallery.htm#Rings
**Phloem** – transport of food and hormones, does not accumulate in rings

Material is moved under positive pressure

5 types of cells
- Sieve cells (pits) – conifers
- Sieve tubes (hardwoods)
- Fibers
- Parenchyma
- Scierids or stone cells – small fiber like cells
Vascular cambium produces xylem and phloem

Cork cambium – located outside functional phloem and produces bark and succulent tissues
Cross Section of a Douglas-fir Stem

**Sapwood**
- physiologically active, water and nutrient movement, carbohydrate storage
- Water flow is driven by transpiration

**Bark**

**Cambium**

**Xylem**
- Sapwood
- Heartwood

**Heartwood**
- dead, contains higher levels of tannins & phenols, provides for structural support

Photo © H.D. Grissino-Mayer [http://web.utk.edu/~grissino/gallery.htm#Rings](http://web.utk.edu/~grissino/gallery.htm#Rings)
Leaf Structure

- Upper epidermis
- Lower epidermis
- Spongy layer
- Palisade layer
- Vein
- Air space
- Guard cell
- Stoma
Cross Section of a Pine Needle

http://biology.uwsp.edu/courses/botlab/Lab08a.htm
Typical Composition of Needles

85-90% water
10-15% dry matter

Dry Matter Composition

- 54% Carbon
- 42% Hydrogen & Oxygen
- 2% Nitrogen
- 1% Ca, K, & Mg
- 1% Other
Photosynthesis – The physiological process plants use to manufacture their own food

Sunlight + carbon dioxide + water is used to produce sugars and oxygen

$$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

Chloroplasts – a type of plastid that contains chlorophyll and is the site of photosynthesis

Chloroplasts are very small - 400,000/mm$^2$
Fate of Light That Strikes a Leaf

<table>
<thead>
<tr>
<th>Light strikes leaf (100%)</th>
<th>Reflected light 10-15%</th>
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<tbody>
<tr>
<td>Absorbed light 80-85%</td>
<td></td>
</tr>
<tr>
<td>Transmitted light 5%</td>
<td>0.5 to 3.5% of light energy used in photosynthesis</td>
</tr>
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</table>

Most absorbed energy lost in heat and in evaporation of water.
Respiration

• The process (oxidation) of converting carbohydrates (sugars and starches) to energy that is needed for cell growth and production of new tissue

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy} \]

• Does not require light
Production and Utilization of Oxygen and Carbon Dioxide by Plants

http://www.spacebio.net/modules/pb_resource/bioregen_lecture/sld027.htm
## Photosynthesis and Respiration

<table>
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<th>Respiration</th>
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<tbody>
<tr>
<td>Produces food</td>
<td>Uses food</td>
</tr>
<tr>
<td>Stores energy</td>
<td>Releases energy</td>
</tr>
<tr>
<td>Uses water</td>
<td>Produces water</td>
</tr>
<tr>
<td>Uses CO₂</td>
<td>Produces CO₂</td>
</tr>
<tr>
<td>Releases O₂</td>
<td>Uses O₂</td>
</tr>
<tr>
<td>Occurs in sunlight</td>
<td>Occurs in dark as well as light</td>
</tr>
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</table>
Movement of Gases and Water Through Stomata

http://extension.oregonstate.edu/mg/botany/photo2.html#figure25
Plant Growth and Development

Three major physiological functions drive growth and development

• Photosynthesis
• Respiration
• Transpiration
**Transpiration** – loss of water vapor from leaf surfaces via stomata and is affected by soil moisture, temperature, humidity, wind (vapor pressure deficit)

**Stomata**
- Open
- Closed

Stomata account for 1% of leaf surface area and 90% of transpired water.

90% of water taken up by roots is transpired.

**Stomatal Opening**
- Photosynthesis
- Temperature
- Moisture stress
- Increased ABA

Guard Cell

http://complabs.nevada.edu/%7Ejbn/bio191lab.htm
Plant Transpiration Is Related to Vapor Pressure Deficit

http://www.spacebio.net/modules/pb_resource/bioregen_lecture/sld030.htm
Water

- 90% of plant
- Photosynthesis and respiration
- Turgor pressure and cell growth
- Solvent for minerals and carbohydrates
- Cooling
- Regulation of stomatal opening
- Pressure to move roots through soil
- Chemical reactions
Abscission of Leaves

- Stem
- Axillary bud
- Abscission zone
- Vascular bundle
- Sclerenchyma
For More Information


Botany Basics http://extension.oregonstate.edu/mg/botany/