Physiological Changes Trees Undergo During Drought Stress

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Presentation Goals

- What tree processes are impacted by drought stress?
- Relationship between insects and drought stressed trees
- Relationship between diseases and drought stressed trees

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Water Stress – What is Affected?

- Reduced growth and productivity
- Affect all operating processes
  - Prevents metabolism and enzyme production
- Resource storage and use
  - Reduced stored nutrients
  - Depletes sapwood-stored water
- Influence timing of processes (flowering, fruit)

Drought & Host Tree Nutrition

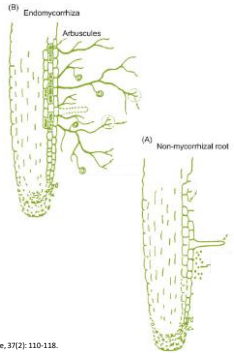
Drought increases nitrogen compounds in leaves
- Nitrogen is used in insect metabolism
  - Foliage eating insect populations increase
  - Caterpillar survival increased with conifer nitrogen

Nitrogen from older leaves moves to young leaves
- Which are more susceptible

Kolb, Fettig, Ayres, Bentz, Hicke, Mathiasen, Steward, and Weed. 2016. Observed and anticipated impacts of drought on forest insects and diseases in the United States. Forest Ecology and Management 380: 321-334.

Drought & Mineral Nutrient Uptake

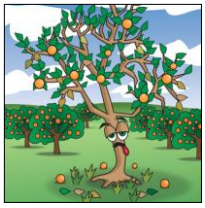
Mineral nutrient uptake from soil is altered during drought
- Mycorrhiza are compromised
- Water movement and root growth are reduced
- Roots become more corky to reduce drying



Mattson, W. and Haack, R. (1987). Role of drought in outbreaks of plant-eating insects. Bioscience, 37(2): 110-118.

Starvation and Water Stress

- Mild-to-moderate water stress
  - Stomata do not close completely
  - Increases defense chemicals
- Severe water stress
  - Stomates close completely
  - Stops photosynthesis
  - Reduces carbohydrates and all metabolic processes
- Defense failure



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https://99designs.com/banner-ad-design/contests/illustrate-starving-citrus-tree-392626

Primary Metabolites

Required for growth and basic function
- Photosynthesis
- Cellular division
- Products of photosynthesis (carbohydrates and sugars)
- Proteins
- Nucleic acids (DNA)

Secondary Metabolites

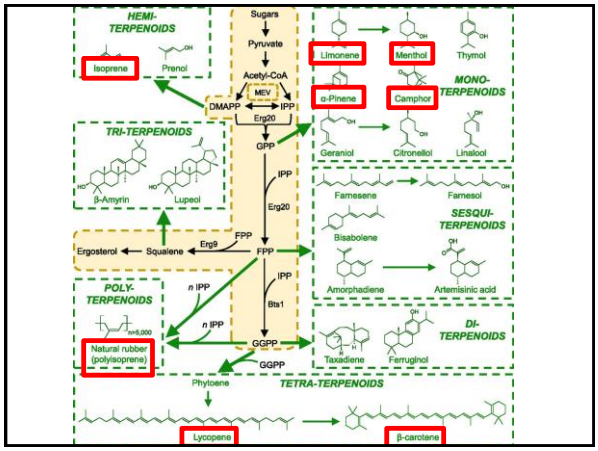
Defense chemicals that fight insects and pathogens

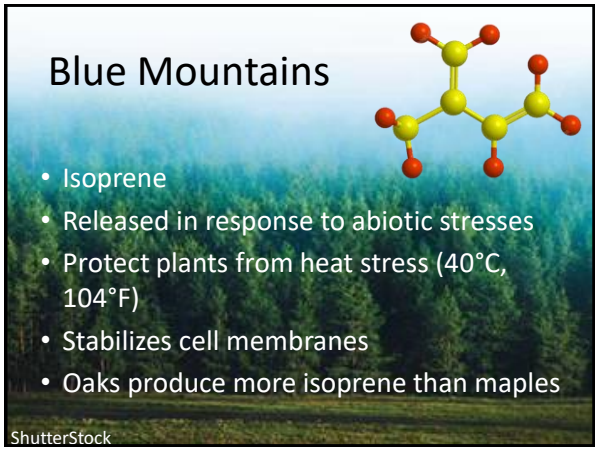
Can also include attractants

–Pollinators – birds, bats, insects

Metabolite Chemicals

- 100,000 identified chemicals
  - 1700 known to be volatiles
- Primary and Secondary chemicals
  - Continuous or reactionary
- Chemicals that can vaporize into a gas
  - Volatile Organic Compounds (VOCs)





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Plant Problems Come In Two Types

Biotic
- Living organisms
  - Pathogens: fungi, bacteria, viruses,
  - Insects: caterpillars, beetles, leaf eaters

Abiotic
- Non-living agents
  - Environmental conditions: precipitation, temperature
  - Pollutants, mechanical injury

Primary vs Secondary Problems

- **Primary problems**
  - Infect healthy trees
  - Pathogens whose reproduction, spread, infection, and survival depend on the plant
- **Secondary problems**
  - Colonize stressed trees
  - Butt and heart rots, many beetles, many cankers

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Drought & Insect Outbreaks

Aggressive bark beetle species
- – Moderate droughts reduce bark beetle population
  - Insect parasites and diseases
- – Severe droughts increase bark beetle performance

Pathogens during low humidity = less disease
- – Drought followed by humidity = more disease

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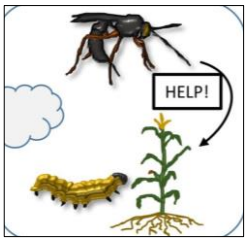
Biotic Problems



- Chemical response to insect or pathogen activity
  - – Insects laying eggs, feeding
  - – Fungus infection
- Attract natural enemies “cry for help”
- Can also attract more “bad” insects

Holopainen, *Tree Physiology*, Volume 31, Issue 12, December 2011, Pages 1356–1377,

Drought Stress – Insects Benefit

- Insects experience improved growth, reproduction, survival after feeding on drought-stressed plants
  - – Some mites, true bugs, and moths and butterfly larvae
- Reduced leaf toughness – more foliage feeding
- Reduced resin and chemicals in resin

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Drought & Insect Senses

- Insects can hear cavitation
- Temperature sensors
- Chemical receptors and can detect VOC
- Compound eyes see even minute color changes

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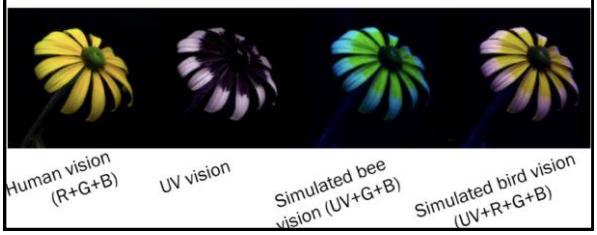
Plants Use Pigmentation for…

- Self protection
  - Ultraviolet radiation and oxidants
- Attractants
  - Insects and microbes
  - May be predators or pathogens of pests



Drought & Insect Senses

- Biochemical and electromagnetic properties of trees change
- Heat and infrared receptors
  - Buprestid beetle (*Melanophila acuminata*) has infrared receptors that help it fire-scorched conifers, where the female lays eggs

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Drought & Altered Defense Chemicals

- Reduced oleoresin in conifers
  - Colonization success of bark beetles
- Insects can detoxify plant chemicals during digestion, less toxic chemicals make them easier to process
- Terpenes are major insect repellents produced by trees are reduced
  - Trees are more attractive

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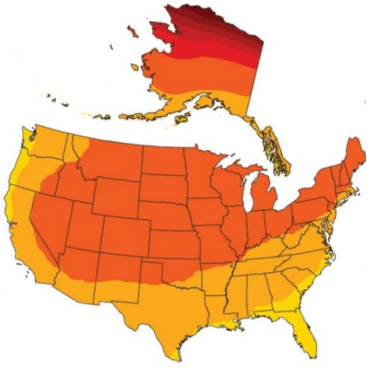
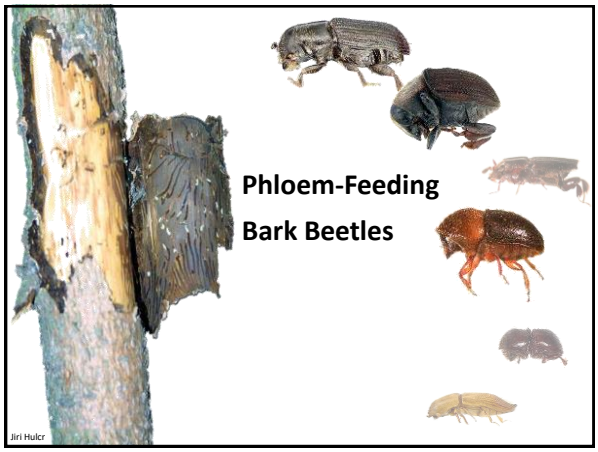
Hot & Dry = More Pest Damage





SE US Bark Beetles

The ***Ips*** engraver beetle

frass (rarely pitch tubes)

The most common "vultures" on pine trees, not primary pests

SE US Bark Beetles

The Black Turpentine Beetle

- Giant globs of resin
- Found in the lower 10 ft of the tree

Ambrosia Beetles

Invasive species:

1) Redbay ambrosia beetle

2) Granulated ambrosia beetle

#1 nursery tree killer in SE USA

ONLY stressed trees!

- flooding
- late freeze
- disease

Jiri Hulcr

Ambrosia Beetles

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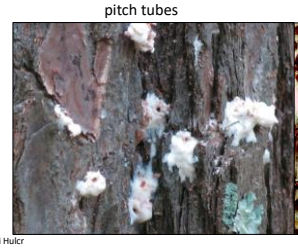
SE US Bark Beetles

The southern pine beetle

pitch tubes

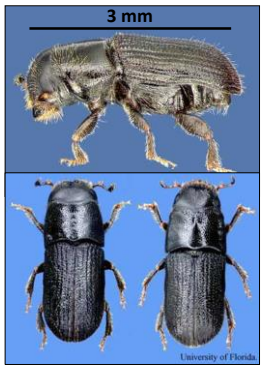


winding gallery, larval "rooms"

Jiri Hulcr

Southern Pine Beetle (SPB)

Dendroctonus frontalis



- Can "mass attack" to kill relatively healthy trees
- Aggressive during outbreaks
- Utilize weak trees when population is low
- Preferred hosts: loblolly, shortleaf, pond, pitch, and Virginia pines

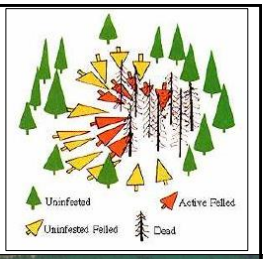
Southern Pine Beetle Infestations

- Infestations develop in spreading "spots"
- Mass attack mediated by pheromone signals
- Spread can be rapid (up to 75 ft/day)
- In outbreak conditions, can kill pines across large areas

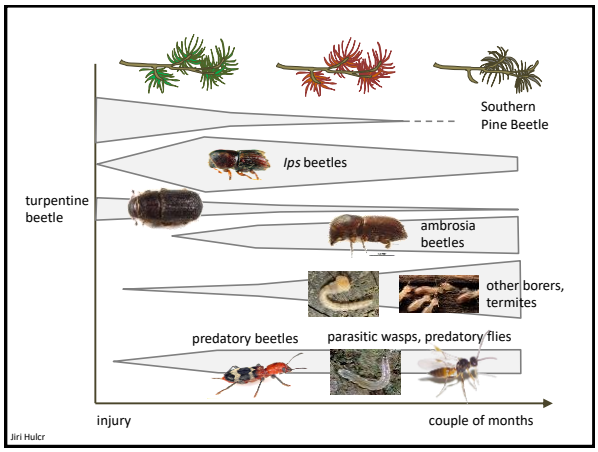
Track Infestation Direction

SPB Management: Suppression

- At earliest detection of an active, spreading infestation (spot), **Cut and Remove:**
  - Cut down & haul out all infested trees
  - 40-70 ft buffer
  - SPBs visually target vertical stem profiles
- Disrupts pheromone signaling for "mass attack"
- Leave dead, vacated trees (for natural enemy development)



SPB Management: Suppression



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VOCs and Dutch Elm Disease

Dutch elm disease

- Bark beetles
- Attract females to lay eggs in the tree

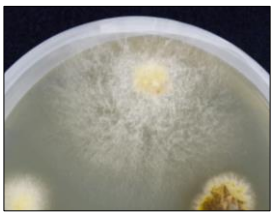
Management:
Watering, reduce stress

- Steph reminder: tell the Tom Green story

https://www.kansasforests.org/forest_health/treedecline.html

VOCs and Verticillium wilt

- Reduced ability to wall off the infection the fungus spreads further into the sapwood
- Drought make symptoms appear faster



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Canker Pathogens During Drought

- Increased of stem canker pathogens
- Trees are less efficient at
  - –compartmentalization
  - –callusing
  - –biochemical defenses

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VOCs and Canker Fungi

- Botryosphaeria cankers
  - redbud, apple, rhododendron, many others
- Cytospora canker
  - Conifers, especially spruce
  - Stone fruit trees, willow, and maple
- Hypoxylon canker of oaks
- Nectria cankers in many hardwoods
- Fusarium cankers
  - Especially following late spring frost injury
- Diplodia (Sphaeropsis) canker on 2-3 needle pines

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VOCs and Root Rots

- Stimulates *Armillaria* to change from resting saprophyte to pathogen
  - dormant rhizomorphs (shoestrings)
- Root rot pathogens of trees are predicted to become more severe and move into new geographic regions
  - Ex. *Armillaria* spp. and *Heterobasidion* spp.
  - *Heterobasidion* could increase in geographic range
    - Currently in the southeastern U.S.

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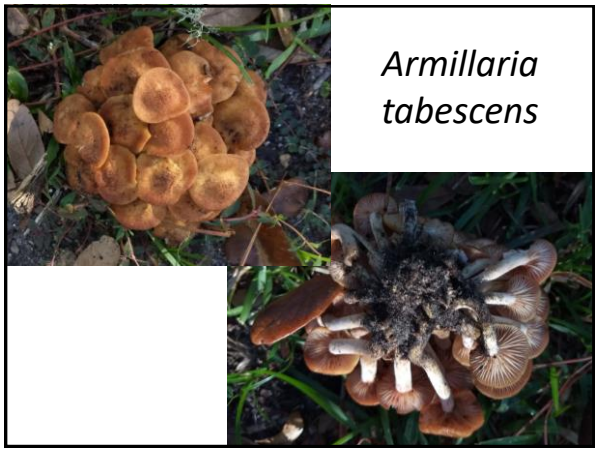
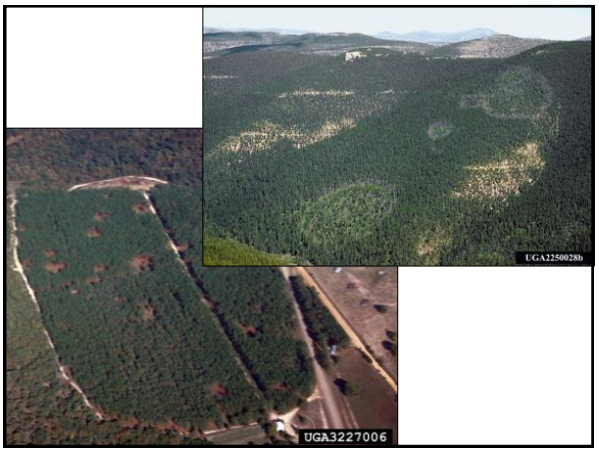
Heterobasidion annosum

Heterobasidion annosum 170714w.JPG. (2017, July 14). *Wikimedia Commons, the free media repository*. Retrieved 05:49, January 5, 2020 from https://commons.wikimedia.org/w/index.php?title=File:Heterobasidion_annosum_170714w.JPG&oldid=251731220.



Armillaria tabescens



Presentation Goals

- Watering trees helps them protect themselves
- Treating trees for secondary problems will help them with recovery
- Identify new plant species that can live with a changing climate

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