

Physiological Changes Trees Undergo During Drought Stress

Stephanie Adams, Ph.D., ISA-BCMA
Tree Pathologist
Plant Health Care Leader, The Morton Arboretum
SAdams@MortonArb.org

Presentation Goals

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

Presentation Goals

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

Water Stress – What is Affected?

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

Drought & Host Tree Nutrition

Drought increases nitrogen compounds in leaves

- Nitrogen is used in insect metabolism

Nitrogen from older leaves moves to young leaves

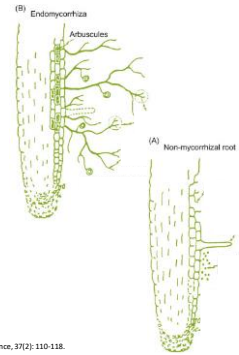
- Which are more susceptible

Koils, 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.

Primary Metabolism

Required for growth and basic function

- Photosynthesis
- Cellular division
- Products of photosynthesis (carbohydrates and sugars)
- Proteins
- Nucleic acids (DNA)

Secondary Metabolism

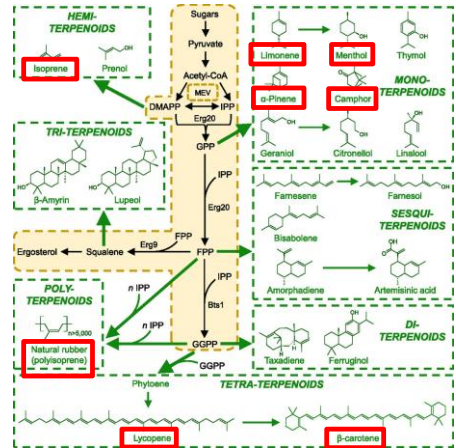
Defense chemicals that fight insects and pathogens

Can also include attractants

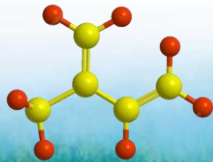
- Pollinators – birds, bats, insects

Plant-Produced Chemicals

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



Blue Mountains

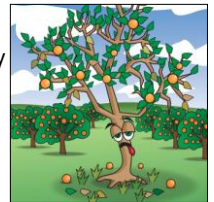


- Isoprene
- Released in response to abiotic stresses
- Protect plants from heat stress (40°C, 104°F)
- Stabilizes cell membranes
- Oaks produce more isoprene than maples

Shutterstock

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



Koib, Fertig, Ayres, Benitz, 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: 323-334.
<https://99designs.com/banner-ad-design/contests/illustrate-starving-citrus-tree-392626>

Presentation Goals

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

Plant Problems Come In Two Types

Abiotic - Non-living agents

- Environmental conditions: precipitation, temperature
- Pollutants, mechanical injury

Biotic - Living organisms

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

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

Koib, 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 & Insect Outbreaks

Aggressive bark beetle species

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

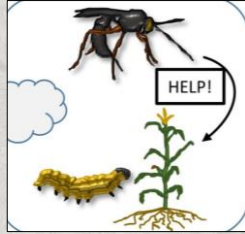
Pathogens during low humidity = less disease

- Drought followed by humidity = more disease

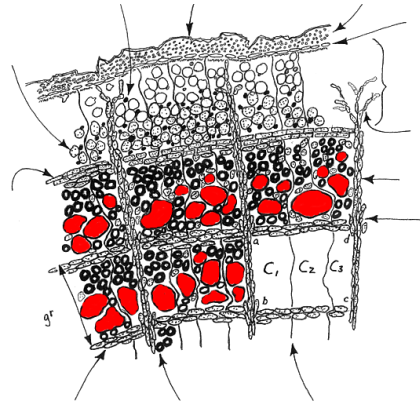
Koib, Fettig, Ayres, Bentz, Hicke, Mathiasen, Steward, and Weed. 2016. Observed and anticipated impacts of drought on forest insects and diseases in the United States. Forest Ecology and Management 380: 321-334.

Biotic Problems

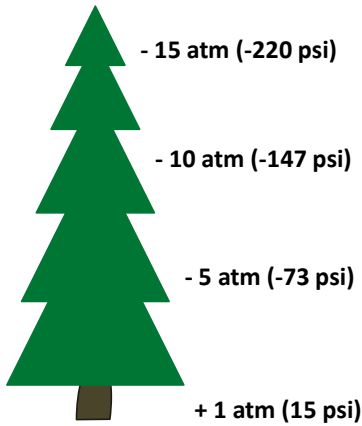
- Chemical response to insect or pathogen activity
 - Insects laying eggs, feeding
 - Fungus infection
- Attract natural enemies “cry for help”
- Can also attract more “bad” insects
- There is also a physical response inside trees...



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

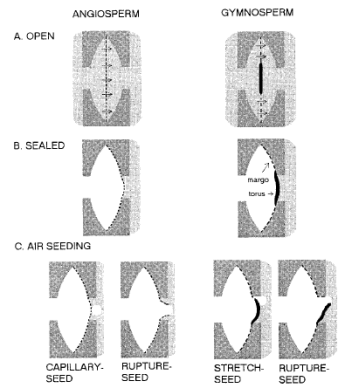


Illustrations, PowerPoints or photos by Edward F. Gilman, Professor, Environmental Horticulture Department, IFAS, University of Florida

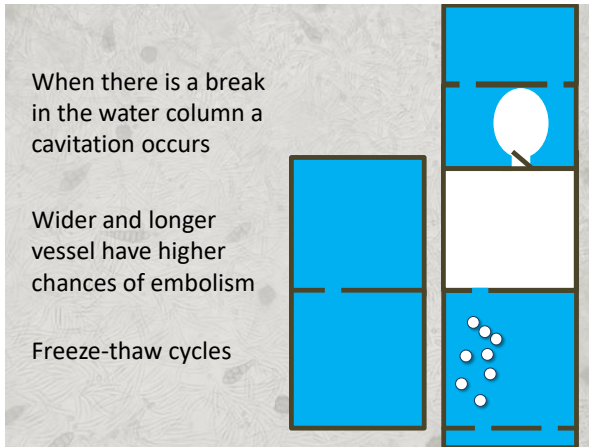


Air Seeding

Air bubble is pulled through the pit because of the different pressure between an air-filled vessels and vessels under tension



(Sperry et al. 1996)



Drought & Insect Senses

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

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

Acoustics of Cavitation

Ultrasound acoustic emission sensor that attaches to the xylem to record cavitation

- Ultrasonic acoustics emissions of cavitation in arborvitae recorded 0.1 – 1 megahertz
- Can last 20-200 microseconds
- Noise attracts insects

Jackson and Grace, 1996. Tyree and Dixon 1983. *Plant Physiology*, Vol. 72, Issue 4, August 1983

Drought & Insect Senses

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

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

Plants Use Pigmentation for...

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

Human vision
(R+G+B)

UV vision

Simulated bee
vision (UV+G+B)Simulated bird vision
(UV+R+G+B)

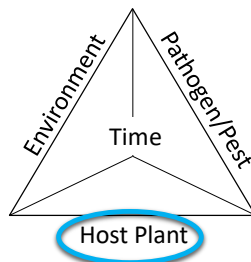
Drought & Altered Defense Chemicals

- 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

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

The Disease/Pest Triangle

- Environment that favors pathogen/pest
- Susceptible host plant
- Virulent pathogen/pest
- Time



Drought & Host Tree Nutrition

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

Drought increases nitrogen compounds in leaves

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

Koib, Fettig, Ayres, Bentz, Hicke, Mathiasen, Steward, and Weed. 2018. Observed and anticipated impacts of drought on forest insects and diseases in the United States. *Forest Ecology and Management* 380: 321-334.

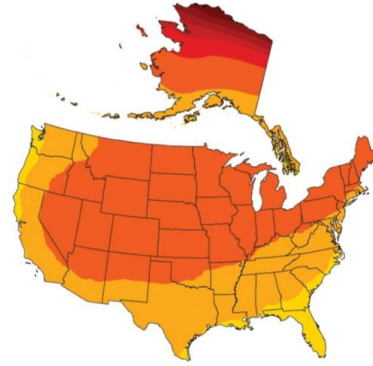
Drought Stress – Insects Benefit

- Insects experience improved growth, reproduction
 - Mites, true bugs, and moths and butterfly larvae
- Reduced leaf toughness
- Reduced resin and chemicals in resin



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

Hot & Dry = More Pest Damage



Phloem-Feeding Bark Beetles



Jiri Hulcr

SE US Bark Beetles

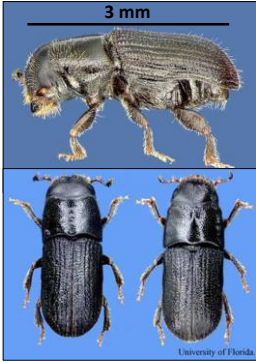
The southern pine beetle



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

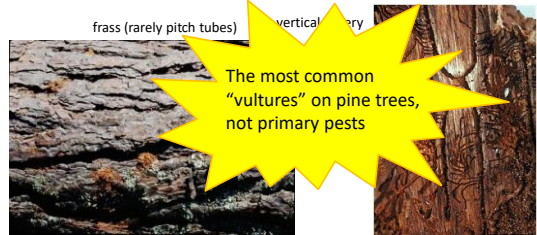


Track Infestation Direction



SE US Bark Beetles

The *Ips* engraver beetle



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



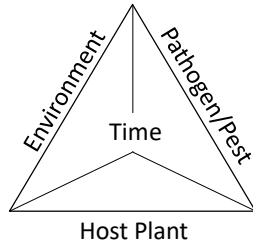
Jiri Hulcr

Presentation Goals

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

The Disease/Pest Triangle

- Susceptible host plant
- Virulent pathogen/pest
- Environment that favors pathogen/pest
- Time



Pathogens During Drought

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

Koib, Fertig, Ayres, Benitz, 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: 323-334.

VOCs and Dutch Elm Disease

Dutch elm disease

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

Management/Prevention:
Watering, reduce stress



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



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

Koib, Fertig, Ayres, Benitz, 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: 323-334.

VOCs and Canker Fungi

- *Botryosphaeria* cankers
 - redbud, apple, rhododendron, many others
- *Cytospora* canker
 - Conifers, especially spruce
 - Stone fruit trees, willow, and maple
- *Biscogniauxia (Hypoxylon)* canker of oaks



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

VOCs and Canker Fungi

- *Nectria* cankers - many hardwoods
- *Fusarium* cankers
- *Diplodia (Sphaeropsis)* canker on 2-3 needle pines



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

Armillaria Root Rot

- Common landscape disease on 700 plant species
- Above ground symptoms are similar to other diseases – early fall color leaf drop, stunted or yellow leaves, dieback



Heterobasidion annosum

- Could increase in geographic range
- Currently in the southeastern U.S.
- *Abies, Acer, Larix, Malus, Picea, Pinus, Populus, Prunus, Quercus, Sequoia, and Tsuga*

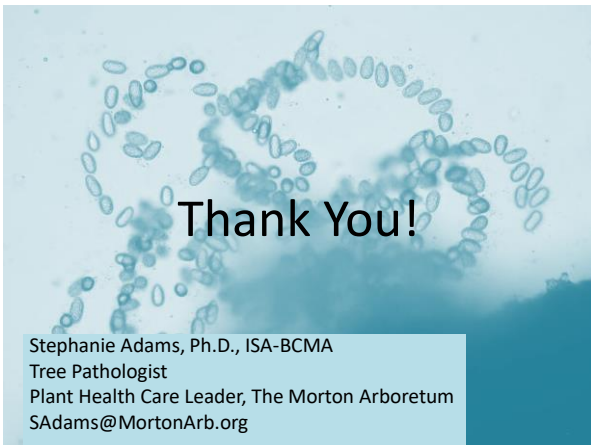


Heterobasidion annosum 170714w.JPG. [2017, July 14]. Wikimedia Commons, the free media repository. Retrieved 05-03, January 5, 2020 from https://commons.wikimedia.org/w/index.php?title=File:Heterobasidion_annosum_170714w.JPG&oldid=251731220.



Summary

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



Thank You!

Stephanie Adams, Ph.D., ISA-BCMA
Tree Pathologist
Plant Health Care Leader, The Morton Arboretum
SAdams@MortonArb.org