HOST PLANT RESISTANCE: HOW CAN WE MAKE BETTER USE OF IT IN A PHC PROGRAM

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What Do We Mean by Host Plant Resistance?

• Those characters that enable a plant to avoid, tolerate, or recover from attacks under conditions that would cause greater injury to other plants of the same species (Painter, 1951, 1958)

• Any plant trait that reduces the preference of herbivores or has a negative effect on the target herbivore (Strauss and Agarwal, 1999).
What Do We Mean by “Tolerance”

- **Tolerance** being the degree to which plant fitness is affected by herbivore damage relative to fitness in the undamaged state or the ability of the plant to regrow and/or reproduce after herbivory (Strauss and Agrawal, 1999).
Host Plant Resistance in the Real World

• Not a “black and white” phenomenon, but more of a spectrum of susceptibility and preference

• American elm is highly susceptible to Dutch elm disease, but new American elm cultivars and new Asian elm hybrids do not contract DED
  – Princeton, Prairie Expedition, New Harmony, St. Croix, Valley Forge
  – Accolade™, Triumph™, Danada Charm™, Commendation™, Cathedral
New American Elm Cultivars and Hybrid Elms
Host Plant Resistance in the Real World

- Certain native and non-native species of viburnum are preferred by viburnum leaf beetle.

- Certain linden and crabapple taxa are preferred by Japanese beetle.

- Green, black and white ash are highly susceptible to EAB, but blue ash appears to be resistant and Manchurian ash is rarely attacked.
Why has HPR Been Slow to Be Implemented?

• Low demand from market place

• Focus has been on ornamental attributes

• High priority placed on plant beauty and “looks”
Why has HPR Been Slow to Be Implemented?

• HPR requires a low aesthetic threshold

• Great diversity of plant material and wide variety of pest and diseases

• Lack of research and funding
Direct Defenses

- Includes mechanical protection and production of toxic chemicals (secondary metabolites)

- Direct defenses are usually expressed as:
  - **Non-preference** - an insect’s response to host characteristics that lead away from the use of the host for food, oviposition, shelter
  - **Antibiosis** - deleterious effects on insect survival or life history
  - **Tolerance** - the ability of a host to grow and reproduce normally while supporting a pest population
Morphological and Mechanical Protection

- Waxy leaf cuticle
- Hairs and setae
- Trichomes
- Thorns
Morphological and Mechanical Protection

- Spines
- Lignification
- Leaf toughness
- Leaf thickness
Examples of Indirect Defenses

• Plant volatiles may be released below ground and protect plants from:
  – Microbes
  – Root-feeding insects
  – Attract natural enemies

• **Down-side:** Exudates from trichomes may provide extra floral nectar (EFN) for squash bug
“Chemical Warfare”
Primary Metabolites

• Essential for plant growth and function
• Occur in the major or primary metabolic pathways
• Consist of carbohydrates, lipids, proteins, and nucleic acids

Glucose
Fructose
“Chemical Warfare”
Secondary Metabolites

- Not essential for plant growth, but by-products of metabolism

- Occur in the secondary metabolic pathways

- Derived from primary metabolites

- Consist of terpenoids, alkaloids, anthocyanins, phenols, quinones
Secondary Metabolites

• Inactive or stored as **phytoanticipins**
  – Glucosinolates, benzoxazinoids, biocidal aglycones

• Activated as **phytoalexins**
  – Isoflavonoids, terpenes, alkaloids

• Protect plants from stress, increase plant fitness, acts as deterrents, inhibit insect growth and development
TERPENES (HYDROCARBONS)

• **Essential oils** (i.e. herbs, perfumes, spices, incense)

• **Resins** (i.e. adhesives, varnishes, insecticides, rosin)

• **Polyterpenes** (i.e. latex, rubber)
An Assortment of Alkaloids

**huperzine A**
Chinese herbal medicine
nootropic

**caffeine**
*Coffea arabica*
study

**reserpine**
Indian herbal medicine
antipsychotic

**coniine**
hemlock
ants, Socrates

**nicotine**
tobacco
Black Leaf 40
insecticide

**vinblastine**
*Madagascar periwinkle*
antileukemic

**strychnine**
*Strychnos nux-vomica*
rodenticide

**D-tubocurarine**
arrow poison, muscle relaxant for surgery

**quinine**
*Cinchona tree, antimalarial*

**saxitoxin**
deadly algal toxin
chemical warfare agent
CIA suicide pill
PHENOLICS
(AROMATIC BENZENE RINGS)

• Flavonoids – anthocyanins
• Tannins – used for tanning leather
• Lignin – gives cell walls their strength
GLYCOSIDES
(GLUCOSE + NONSUGAR)

- Glucose + terpene
- Glucose + steroid
- Glucose + phenolic compound

- **Saponins**
  - Shampoos and detergents

- **Cardio active glycosides**
  - Digitoix and heart medicines

- **Cyanogenic glycosides**
  - Contained in cassava
  - Deadly poisons
“Examples of Chemical Warfare”

• Lignin (phenolic) limit pathogen entry by physically blocking or increasing leaf toughness

• Quinones (oxidized phenols) inhibit protein digestion and can be toxic

• Salicylic acid (SA) affects growth of winter moth larvae
“Examples of Chemical Warfare”

- **Flavonoids** help defend against abiotic and biotic stresses
  - UV radiation, pathogens, insect pests
  - Act as feeding deterrents, anti-feedants, possess anti-fungal properties

- **Tannins** bind to proteins, reduce nutrient absorption cause gut lesions in insects
“Examples of Chemical Warfare”

- Lectins (glycol-proteins) are toxic and interfere with digestion and nutrient absorption
Indirect Defenses

• Production and release of a mixture of volatile chemicals designed to:
  – Attract parasitoids and predators of the pest insect
  – Provide supplemental “housing” and food (extra floral nectar)
Examples of Indirect Defenses

• Activated by a combination of mechanical damage and elicitors from attacking insects

• Herbivore induced plant volatiles (HIPVs) include:
  – Terpenes
  – Green leafy volatiles (GLVs)
  – Ethylene
  – Methyl salicylates (Sas)

• GLVs and SAs attract predatory mites, big-eyed bug, ladybird beetles, and green lacewings
WHY DO INSECTS FEED ON SOME TREES AND BUT NOT OTHERS?
WHAT ABOUT LEAF THICKNESS, TOUGHNESS, AND LEAF CHEMISTRY
Elm Leaf Beetle
Japanese Beetle, Gypsy Moth, Cankerworm, Elm Leafminer, Arborvitae Leafminer
WHAT HAVE WE LEARNED?

• There is a rich pool of *Ulmus, Tilia, Quercus, Carpinus* taxa for future tree breeding efforts

• Leaf morphology and chemistry appears to effect feeding preference and suitability and insect development
  – Absence or presence of *trichomes*
  – Leaf *phenolic* concentrations
  – Leaf *surface waxes*
  – Leaf *toughness*
# LEAF THICKNESS AND TOUGHNESS FOR *Tilia* Taxa by Origin

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<tr>
<th>ORIGIN</th>
<th>LEAF THICKNESS (mm.)</th>
<th>INNER LEAF TOUGHNESS (kg)</th>
<th>OUTER LEAF TOUGHNESS (kg.)</th>
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<tbody>
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<td>ASIA</td>
<td>0.020a</td>
<td>0.025b</td>
<td>0.020a</td>
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<tr>
<td>EUROPE</td>
<td>0.021a</td>
<td>0.019a</td>
<td>0.019a</td>
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<tr>
<td>NORTH AMERICA</td>
<td>0.022a</td>
<td>0.022ab</td>
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</table>

**Significance:**

- NS
- F=8.1; P=0.02
- NS
LEAF THICKNESS AND TOUGHNESS FOR *ULMUS* AND *QUERCUS* TAXA BY ORIGIN

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</table>

*Significance:*  
*F*=70.0; *P*<0.001  
*F*=31.3; *P*<0.001  
*F*=39.2; *P*<0.001

*U. parvifolia*  
0.24  
0.051  
0.056

*EUR-NA OAKS*  
0.19  
0.029  
0.030b
What Have We Learned?

• Leaf toughness and thickness of *Carpinus* spp. was correlated with gypsy moth larval longevity and pupal weights
What Have We Learned?

• Elm leaves with greater chemical diversity were correlated with adult gypsy moth emergence and Japanese beetle feeding.

• Gypsy moth emergence was correlated with leaf lipid diversity.

• No significant correlation was found between elm leaf lipid diversity and Japanese feeding preference.
What Have We Learned?

- Adult Japanese beetles frequently visited surfaces treated with a wax extract from preferred elm species compared to less preferred elm species.
Host Evasion

• Host avoids a pest by passing through a susceptible stage before insect emergence or injury

• Utilizes pest biology and host plant phenology

• **Example:** elm leaf miner and elm phenology
Plant Architecture and HPR

- Shape
- Growth habit
- Height
- Canopy density
- Color
Reversing the Tables
Bronze birch borer and white-bark birch

• Example of a native pest and a non-native plant

• North American birches had >70% survival

• Asian and European birches had 0% survival
Plant Stress and HPR

• Plants tend to release volatiles when under stress attracting:
  – Bronze birch, honeylocust, and two-lined chestnut borers
  – Conifer and hardwood bark beetles

• Outbreaks of bronze birch borer have been associated with drought
Plant Stress and HPR

- When under drought stress, EAB larvae performed better on Manchurian ash.

- Conifers are vulnerable to bark beetle attacks when under stress due to reduced resin flow.
What About Fertilization and HPR? (Herms, 2002)

• Common thought is fertilization enhances pest resistance
• Research data does not really support this practice
• Studies have shown fertilization can reduce plant resistance to pests and increase pest outbreaks
  – Increases nutritional quality of host plant
  – Reduces production of secondary metabolites
Growth-Differentiation Balance Hypothesis (GDBH) and HPR

- Postulates a physiological trade off between growth and secondary metabolism

- Predicts a parabolic response of secondary metabolism to variation in nutrient availability

- Fertilization of moderately nutrient-deficient plants may decrease secondary metabolism if growth is increased, but photosynthesis is not affected
Fertilization, Secondary Metabolites, and Photosynthesis

• Fertilization of extremely nutrient-limited plants may increase secondary metabolism if photosynthesis is also increased.

• There is no strong evidence that fertilization increases tolerance to woody plant defoliation.
Fertilization, Nitrogen, and Host Plant Resistance

• Rate of nitrogen (N) applied appears to be key factor affecting plant growth

• Form or method of application of N has shown little effect

• Suggests insect performance is influenced more by general plant response than fertilizer formulation
Prescription Fertilization and Host Plant Resistance

• **Prescription fertilization** can be highly effective and strongly recommended

• Fertilization programs must be tempered with knowledge and understanding of pest population dynamics and potential pest management consequences
Benefits of Using HPR

- Reduces use of chemical pesticides
- Reduces potential for pesticide resistance
- High economic value of ornamental plants
Benefits of Using HPR

• High cost of plant maintenance

• Potential sustainability and effectiveness

• Minimal impact on natural enemies

• Relatively low cost of implementation
Limitations of Using HPR

- Lengthy process involving years
- Strong desire for ornamental plant attributes
- High priority on aesthetics
Limitations of Using HPR

• Damage thresholds can be quite low

• Great diversity of ornamental plants and accompanying pests

• Lack of research and funding
Implementing HPR into a PHC Program

• Properly select and site plants

• Keep existing plants healthy

• Know your pest complex

• Use readily available plants suited for your area
Implementing HPR into a PHC Program

- Use native plants, where possible
- Select low maintenance plants that are not as susceptible to pests and diseases
THANK YOU FOR YOUR ATTENTION!