The Art of the Diagnosis
Richard Buckley
Rutgers University
New Jersey Agricultural Experiment Station
Rutgers Cooperative Extension
School of Environmental and Biological Sciences
Plant Diagnostic Laboratory

Sentinel Plant Network
National Plant Diagnostic Network
First Detector Training Program

Plant Pathology 101

• Pathology:
  – The scientific study of the nature of disease and its causes, processes, development, and consequences.
  – The anatomic or functional manifestations of a disease.
  – A departure or deviation from a normal condition.

• Pathologist:
  – Specialist in the structural and functional changes caused by disease.

Plant Pathology 101

• Plant Disease:
  – Any disturbance of a plant that interferes with its normal structure, function, or economic value.
  – Any condition of a plant that is contrary to grower expectations.

Plant Pathology 101

• Plant Disease: a condition of abnormal physiology in a susceptible host plant that is a result of the plant’s constant association with a disease causing agent within a set of favorable environmental conditions.

The Triangle: Host Plant Condition

• Most plants resist or tolerate attack
• Plant must be susceptible to attack
• Resistance and susceptibility different degrees of the same thing
  ✔ Influenced by genetics
  ✔ Influenced by environment
• Immunity is absolute
The Triangle: Causal Agents

1. **Biotic** (infectious)
   - Organism (pathogen) grows, multiplies, and spreads to other plants
   - 10% of plant problems reported

2. **Abiotic** (non-infectious)
   - Environmental conditions that impact plant development (physiogens)
   - Much more common: 90% of plant problems reported (injury not disease)

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**Biotic Causal Agents - Pathogens**

- Fungi
- Bacteria
- Virus
- Viroid
- Mollicute
- Protozoa
- Algae
- Insect
- Mite
- Parasitic plant
- Nematode

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**Path 101: Causal Agent**

- Pathogen must be present
- Pathogen must be pathogenic
- Pathogen must be virulent
  - Influenced by genetics
  - Influenced by environment

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**Abiotic Causal Agents - Physiogens**

- Physical factors
  - Temperature
  - Moisture
- Chemical factors
  - Air pollutants
  - Pesticides
  - Fertilizers and salts
- Mechanical factors
  - Everything else

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The Triangle: Environmental Condition

- Provides pathogen opportunities
  - Influences host plant condition
  - Increases pathogen virulence
- Predisposing conditions
  - Site
  - Weather
  - Management
Path 101: Recognizing Diseases

- **Symptoms** –
  - Observable condition of abnormal physiology in the plant

- **Signs** –
  - Physical presence of the causal agent or clear evidence of abiotic stress factors

**Symptoms:**
leaf spot, blight, tip blight, dieback, flagging, chlorosis, necrosis, canker, wilt, root rot, witches broom, mottling, intervein al necrosis, epinasty, scorch, crown rot, defoliation, boring phyllody, leaf blotch, root, damping off, soft rot, mummification, stem pitting, gall, shot-hole, bleeding, slime flux, blast, scald, bronzing, staghead, tumefaction, fasciation, hairy root, knots, enation, shoestring, erinos, stipples, notching, charring, skeletonization, rupose, puckering, edema, intumescence, russet, scab, callus, leafroll, leaf curl, croziers, dwarfing, stunting, rosetting, atrophy, etiolation, spiralism, hyperelongated, bunchy, cresting, dead

**Blight, Dieback, Flagging**

Multiple terminology for the same symptom!

**Aster Yellows**

- **Symptoms:**
  - stunting
  - chlorosis
  - phyllody
  - witches broom

**Pine Bark Beetle**

Larvae leave distinct galleries
Wilt symptom = what cause?

Path 101: Recognizing Diseases

- Symptom caveats and cautions
  - Not the be all – end all
  - Simple starting point
  - Don’t jump to conclusions
  - Need more information

Signs:
Fruiting body, sporocarp, cleistothecia, pycnidia, mycelium, hyphae, stroma, spore, conidia, sclerotia, conidiophore, perithecia, apothecia, synnema, cyst, egg, cast skin, nematode, insect, pupal exuvia, honeydew, frass, plasmodium, sporodochia, acervulus, aecium, oospore, zoospore, cirrhus, basidiocarp, ascus, sporangium, teliospore, uredium, mushroom

Cedar Apple Rust
Telia on Eastern red cedar

Dogwood Anthracnose
The fungus moves into small stems and causes dieback

Downy Mildew of Sunflower
Conidiophores and conidia
Path 101: Recognizing Diseases

- Signs caveats and cautions
  ✓ Not the be all – end all
  ✓ Simple starting point
  ✓ Don’t jump to conclusions
  ✓ Need more information

Path 101: The Burden of Proof

Koch’s Postulates: Establishing a Cause-Effect Relationship

1. Suspected pathogen must be constantly associated with specific symptoms over time and space
2. Suspected pathogen must be isolated into pure culture and identified
3. Same symptoms are reproduced when suspected pathogen is introduced to healthy plants
4. Suspected pathogen re-isolated from symptomatic plants and identified

Path 101: Basic Diagnostics

1. Identify the plant
2. Observe the symptoms
3. Evaluate the predisposing conditions
4. Identify the sign
5. Synthesize the information

Step #1: Identify the Plant

- Understand the needs of the plant
  ✓ What are the horticultural requirements of this plant?
- Provides a list of pathogens
  ✓ Key plant / key pest concept
Cupressaceae very hard hit by extreme weather conditions

Heat and Drought Stress

Photos: Richard Buckley, NJAES

Volutella Leaf and Stem Blight

Photos: Richard Buckley, NJAES

Step #2: Observe Symptoms

- Define the problem
- Examine the entire plant
- Examine the plant community
- Recognize patterns
- Observe symptom progression
- Recognize classic symptom expression

Know your plant materials!

- Proper identification is key
- Understand the needs of the plant
- What are the horticultural requirements?

Step #2: Observe Symptoms

- Define the problem
- Examine the entire plant
- Examine the plant community
- Recognize patterns
- Observe symptom progression
- Recognize classic symptom expression

Yank it out of the ground!

Peachtree Borer

Photos: Richard Buckley, NJAES
**Botryosphaeria Canker**

Don’t be afraid to cut it up!

**Define the problem!**

- Identify dysfunctional plant part or plant system
- What kind of symptoms do you see?

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**Step #2: Observe Symptoms**

- Define the problem
  - Examine the entire plant
  - Examine the plant community
  - Recognize patterns
  - Observe symptom progression
  - Recognize classic symptom expression

**Community Symptom Expression**

Similar symptoms on unrelated plants are likely due to a non-living (abiotic) cause

Similar symptoms on related plants are likely due to a living (biotic) cause

**Recognize Patterns**

- Uniform - abiotic
- Random - biotic
Step #2: Observe Symptoms

- Define the problem
  - Examine the entire plant
  - Examine the plant community
  - Recognize patterns
  - Observe symptom progression
  - Recognize classic symptom expression

Observe Symptom Progression

- Progressive - biotic
- Non-progressive - abiotic
Step #2: Observe Symptoms

- Define the problem
  - Examine the entire plant
  - Examine the plant community
  - Recognize patterns
  - Observe symptom progression
  - Recognize classic symptom expression

Typical Symptoms of Fungal Pathogens

- Fungi cause most plant diseases
- Fungi attack all plant parts and cause all possible symptoms
  - Central infection point
  - Rounded, even borders
  - Discolored margins
  - Dry rot
  - Signs frequently produced
Crown and Root Rot

Particular pathogens attack particular plant parts
Note: dry rot, discolored cambium, even border

Maple Anthracnose

Note: the gelatinous amber colored acervuli

Xylella fastidiosa

Single-celled bacterium with rippled cell walls that multiplies through binary fission.

Xanthomonas campestris

Bacteria are found in every ecological niche
Large colonies form a biofilm: an extracellular polysaccharide ooze

Typical Symptoms of Bacterial Pathogens

• Bacteria attack all plants, but are most common on herbaceous hosts
  ✓ Infection through natural openings or wounds
  ✓ Angular borders
  ✓ Chlorotic halo
  ✓ Water soaked rot
  ✓ Tissue blight
  ✓ Rotten smell

Bacterial Leaf Spot
Fire Blight

Bacteria oozes from natural openings on infected trees

Fire Blight

Pollinators carry bacteria to nectar cells in flowers, which results in “spur blight”

Fire Blight

Branch dieback “shepherd’s crook”
Note: the damage increases as long as the weather permits

Erwinia Soft Rot

Photo: Richard Buckley, NJAES

Tobacco Mosaic Virus

Bacterial streaming

Photo: Sabrina Tirpak, NJAES
Typical Symptoms of Viral Pathogens

- Virus attack many plants and cause unusual symptoms
  - Abnormal growth
  - Abnormal color
  - Latent or symptomless hosts
  - Look for the vector

Cucumber Mosaic Virus

Hosta Virus X

Impatiens Necrotic Spot

Impatiens Necrotic Spot

Variable symptoms on unrelated plants

Virus Vector – Western Flower Thrips
Penstemon infection confirmed with ELISA test strips

Insects with piercing-sucking mouthparts

Typical Symptoms of Sucking Insects

- Sucking insects attack all plant parts
  - Stipple
  - Discolored foliage
  - Distorted growth
  - Defoliation and branch dieback
  - Signs frequently produced

Insects with piercing-sucking mouthparts leave spots where the mouthparts were inserted into the plant

Heavy feeding may distort foliage

Small feeding wounds are called stipple
Heavy feeding takes the color out of the tissues
Elm Lace Bug

Signs are frequently produced; waste products, cast skins, eggs, or the critters themselves. Insects are our friends!

Eastern Spruce Gall Adelgid

Nymph feeding causes elongate, pineapple shaped galls on new growth in the spring. Galls are found on the base of the twigs.

Peachtree Borer

Insects with chewing mouthparts

Typical Symptoms of Chewing Insects

- Complete defoliation
- Specialized feeders
  - Skeletonization
  - Holes and notches
- Nest makers
  - With silk and/or plant parts
  - Borers and minors
  - Due to growth-regulator effects

European Pine Sawfly

Gregarious larvae chew all of the needles

Japanese Beetle

Japanese beetles skeletonize the leaves of many plants
Leaf notching by adult weevils

Annual Bluegrass Weevil

Fall Webworm

Makes silk nests that expand to cover entire branches

Makes nests by weaving together plant parts

Bagworm

Boxwood Leafminer

Flies mine tissues within leaves

Midges (flies) also cause various gall-like maladies of trees and shrubs. Midges mostly mine leaves.

Lilac Ash Borer

Ocellate Maple Eyespot Gall

After feeding in the cambium, larvae bore through the heartwood, create a plug, then pupate and exit out the opposite side.
**Typical Symptoms of Physical Injury**

- Tip and edge scorch
  - On individual plant parts
- Top down/outside in
  - On entire plants
- Premature defoliation
- Poor growth

**Moisture Stress**

- Loss of turgor first symptoms of drought

**Temperature and Moisture Stress**

- Scorch after drought and high heat stress
  - Note: tip and edge; most leaves in the canopy affected

**Temperature and Moisture Stress**

- Needles wilt and scorch too

**Temperature and Moisture Stress**

- Interior needle browning normal reaction to sub-acute stress

**Moisture Stress**

- Tip and edge scorch over entire plant
  - Top-down / outside-in injury
Temperature and Moisture Stress

Damage is more severe on tough sites – July 11, 2010

Typical Symptoms of Chemical Injury

- Necrosis of exposed plant parts
  - Due to direct contact with product
- Tip and edge necrosis
  - Due to uptake and translocation of product
- Abnormal growth and color
  - Due to growth regulator effects
  - Due to imbalances of nutrients

Drop Spreader Disease

Pattern matches application technique; The cause and effect are clearly evident

Contact Phytotoxicity

Burn from horticultural oil application on cloudy day

Phytotoxic Uptake and Translocation

Injury to new growth due to Imprelis uptake; Do not apply under the drip-line!

Growth Distortions

Dicamba distorts flowers and causes upward cupping of leaves; this sample injured by drift
Contact Phytotoxicity

De-icing salt damage; note the pattern

Phytotoxic Uptake and Translocation

Sodium and chloride (as are many other specific ions) are absorbed and moved to the leaf tips where they build to toxic concentrations

Iron Deficiency

High pH binds Fe in the soil and causes deficiency symptoms

Toxicities, deficiencies, and imbalances cause color problems or burns

Typical Symptoms of Physical Injury

- Breaks, bruises, cracks, punctures, chewing, pecking, girdling, root pruning, construction, wind, rain lightning, ice, snow...

Lightning Strikes

Winter Injury

Heavy snow breaks branches and knocks stuff over
Wind Thrown

Note: the lack of root biomass and the poor drainage

Construction Damage to the Roots

Do nothing under the drip line!

Photo: Richard Buckley, NJAES

String Girdling

Photo: Ann Gould, NJAES

Step #3: Recognize Predisposition

• Analyze the site
  ✓ Drainage
  ✓ Root space
  ✓ Shade and exposure
  ✓ Air movement
  ✓ Contour
  ✓ Soil chemical properties
  ✓ Soil physical properties

Step #3: Recognize Predisposition

• Analyze the site
• Record the weather
• Evaluate the management program

Wet Feet

Taxus does poorly on wet sites, but Phytophthora does well
Damage most severe on exposed surfaces (NE side or Ocean side)

Winter Injury

Frozen roots and wind exposure did this planting in

Clay, Compaction, and Poor Drainage

How do you know unless you look?

Pachysandra Leaf and Stem Blight

Step #3: Recognize Predisposition

- Record the weather condition
  - Temperature
  - Degree day accumulations
  - Precipitation
  - Relative humidity
  - Evapotranspiration rate
  - Deviations from normal
  - Yearly trends

Frost Damage

Cold temperatures damage new growth; Cause and effect clearly evident
Entomosporium Leaf Spot

Botryosphaeria Canker

Brown Patch
*Rhizoctonia solani* Predictive Model

- Warm nights
  - Soil temperature >61°F
  - Air temperature >59°F
- Extended leaf wetness
  - 95% RH for >10 hours
  - 0.1" rain or irrigation in preceding 36 hours

Step #3: Recognize Predisposition

- Evaluate the management program
  - Irrigation input and method
  - Fertility inputs
  - Pesticide use
  - Cultivation and mulching
  - Pruning

Wet Feet

Excessive Mulch!
You Did What!?!?

Cupressaceae very hard hit by heat
(Poor planting technique, crummy mulch, and landscape fabric didn’t help much)

Insecticide Drift

Spray the tree, kill the grass!

Ruh Roh!?!?


Step #4: Identify the Sign

- Macroscopic observation
- Insect traps and collections
- Microscopic observation
- Pathogen stimulation
- Pathogen isolation
- Antibody based test kits
- Polymerase chain reaction

Red Thread

Pseudosclerotia “Red threads” form on leaf tips

Macroscopic Dissecting Microscope Hand-lens
10 to- 60x Magnification
Swiss Needlecast

Needles appeared scorched from the winter

Use a hand lens to monitor mite populations

Annual Bluegrass Weevil and Black Turfgrass Ataenius

Dissecting scope reveals spot ID characters of insects

Compound Microscope

40 to 400x Magnification

Macrophoma Leaf and Stem Blight

Macrophoma buxi pycnidia under macroscope
Macrophoma Leaf and Stem Blight

*Macrophoma buxi* conidia under microscope

Boxwood Blight

Incubate leaves to stimulate fungal growth

Boxwood Blight

*Calonectria pseudonaviculata* under the scope

Cyclamen Wilt

"ET" finger

Bacteria laden “sterile” water is then streaked on media: Which one is the pathogen?

Isolates are subjected to a battery of biochemical tests

selective media

only allows target to grow

Photos: APS Press

differential media makes target look different

Photos: APS Press

Photos: APS Press
Antibody-based test kits for Pythium detection

Polymerase Chain Reaction (PCR)
- Amplifies many-fold tiny bits of DNA from the target organism
- Very sensitive
- Method of choice for research and regulatory efforts
- Types:
  - Standard
  - Real-time PCR

Step #5: Synthesis the Information
- Consider the symptoms
- Recognize the predisposing factors
- Identify the sign
And put it all together!

!!Caution!!
- Fungi don’t read the book
- Don’t jump to conclusions
- Keep an open mind
- Expect the unexpected
- Accumulate information
- Use your resources
- Act on your hunches – decide!

Questions?

Thank You Very Much!