FACT SHEET
Agriculture and Natural Resources
PP401.03

This is the third fact sheet in a series of nine designed to provide an overview of key concepts in plant pathology. Plant pathology is the study of plant disease including the reasons why plants get sick and how to control or manage healthy plants.

20 Questions on Plant Diagnosis

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Overview

Proper diagnosis of plant problems is a key factor in plant health management. As urban forester Alan Siewert quips: "Treatment without diagnosis, as in medicine, is malpractice." Despite this, diagnostics is often not given adequate attention.

There are three challenges to consider when embarking on plant problem diagnostics:

- Some plant problems are very obvious, while other problems are very obscure.
- Some plant problems will not be diagnosed with your first effort. In fact, some plant problems may never be fully diagnosed.
- Clients usually want an immediate and clear cut answer which produces great pressure to provide a quick-draw, clear-cut diagnosis.

Typically, diagnostics is a process to come up with the best possible explanation of why a good plant has gone wrong. Unfortunately, it almost always involves unknown variables and uncertainties that make an absolute slam-dunk diagnosis the exception rather than the rule. This reality sometimes conflicts with our desire to provide quick, clear answers. Remember that an incorrect diagnosis will lead to an incorrect treatment. Speed should never supersede accuracy.

Figure 1. Characteristic "leaf skeletonizing" damage caused by Japanese beetles. (Photo by Joe Boggs)

However, if the plant problem is an insect pest and the pest is present, a quick and accurate diagnosis can be made by simple pest identification. Diagnosing what is causing leaves on little leaf linden to become skeleton-like with only the veins remaining is relatively easy if Japanese beetles are swarming the tree.

Of course, you should always remain aware that a plant may be suffering from multiple problems, and the most obvious may not be the most significant. The plant problem diagnostic process is not unlike our judicial process and the same dangers associated with "pre-judging" also apply. Starting with a diagnosis, then selectively gathering facts to support the diagnosis is likely to produce an incorrect diagnosis; to wrongly convict. Plant problem diagnostics should be guided by the axiom: ***don't*** make the symptoms fit the diagnosis; ***do*** make the diagnosis fit the symptoms.

Plant problem diagnostics should follow a systematic approach to finding proper treatment, and the place to begin is to consider the questions that must be answered. You do not necessarily need to know the answers to all of the questions, nor do you have to ask them in order. Often, however, failure to accurately answer some of the early basic inquiries at the start is the reason for the faulty diagnosis.

Question 1: What is the plant?

This is the first of three key questions concerning the plant itself. It is one of the reasons why truly useful, comprehensive diagnostic keys are so difficult to create; the plant ID key alone would be huge. In diagnosis and treatment, determining whether a plant is a pine or a spruce, determining if it is naturally variegated or deciding if it is supposed to be a dwarf are all crucial.

Be cautious with common names. White ash (*Fraxinus americana*) and mountainash (*Sorbus americana*) are good examples. Both have compound leaves; however, the arrangement of the leaves on the stems provides the first clue that these trees are not related. Ash trees have compound leaves attached opposite to one another on the stem while the leaves of mountainash are attached in an alternate pattern. How the common names are written also show that these trees are unrelated. Mountainash is not a "true ash," so the name is written as a contraction. A hyphen may also be used to denote the same thing as in the case of stinking-ash (*Ptelea trifoliata*), which is not a "true ash."

Spend time focusing on what plant you are looking at or having described to you. Many diagnoses flounder by initial misidentification. Identifying a plant properly leads to a focused consideration of questions such as the ones that follow.

Question 2: What is normal for the plant?

Plant characteristics are variable enough that what is perfectly healthy for one plant may be a sign of a serious problem for another. A good example can be found in deciduous conifers such as baldcypress, dawn redwood, and larch. These three trees bear cones and needles, and neophyte plant lovers may think they are evergreens.

However, they are indeed deciduous, with fall colors ranging from spun gold to reddish brown, followed by leaf drop. Many a baldcypress has felt the bite of the saw from new homeowners who notice a completely brown-leaved tree in their new landscape in late fall. Indeed this total browning of foliage would be a sign of almost certain death on a true evergreen conifer, such as pine. Knowing how to identify these deciduous conifers and understanding that their fall color and leaf drop is normal can be all you need for proper diagnosis.

Similarly, knowing that some yews, such as *Taxus* 'Helen Corbit', naturally have needles trimmed in bright yellow should give a horticulturist pause if someone wonders if the yellowing is due to photosynthetic-inhibitor herbicide injury. Knowing that leaves of Naruto Kaede trident maple (*Acer buerganum* 'Naruto Kaede') naturally curl-up along the edges will reduce the chances that the leaf curl will be diagnosed as being caused by moisture stress, herbicide injury, or aphids. Knowing that the needles of dragons-eye pine (*Pinus densiflora* 'Oculus Draconis') naturally have yellow banding will help prevent a recommendation to treat for a needle-caste disease. Knowing that the greenish, strap-like bracts on lindens naturally turn brown after flowering is key to responding to a concern that the browning is associated with some type of fungal disease.

Figure 2. Baldcypress with fall color; it is a deciduous conifer. (Photo by Joe Boggs)

Figure 3. *Taxus* 'Helen Corbit' foliage is variegated with needles trimmed in yellow. (Photo by Joe Boggs)

These examples do not prove there is nothing wrong with the plant. After all, the *Taxus* and trident maple may very well also have herbicide injury, and there may still be diseases on the pine and linden. Nevertheless, knowing what is normal for a particular plant provides a great early perspective in the diagnostic process.

Question 3: What are the common problems with the plant?

Another good diagnostic perspective is to consider a plant's common problems. All plants have their own set of diseases, insect problems, and cultural dilemmas; there are no problem-free plants. Pondering these common quandaries can create somewhat of a bias, especially if you are seeing something new, but it helps rule certain problems out.

For example, fire blight, caused by the bacterium *Erwinia amylovora*, causes a blighting of shoots that result in discolored leaves and a curling of the shoot often characterized as a "shepherd's crook." This symptom is helpful in considering fire blight as a possibility. However, such symptoms can also be caused on many plants by far simpler problems, such as moisture stress, resulting in leaf and shoot wilting. For which plants should fire blight be considered a possibility? As it turns out, fire blight occurs only on plants in the rose family (Rosaceae). So if you see a crabapple, firethorn, or mountainash with a shepherd's crook symptom, fire blight should be considered and investigated. If the plant is a maple, white ash, or pine — not members of the rose family — fire blight is not a possibility.

Some plant problems are specific to a particular genus. Native ash trees (*Fraxinus* spp.) in North America are under threat from the non-native emerald ash borer (*Agrilus planipennis*). Ash trees are members of the olive family (Oleaceae); however, other members of this family, such as lilacs and forsythia, are not threatened by the borer. As noted above and in question #1, since mountainash belongs to the rose family, it may suffer from fire blight but it will not be attacked by emerald ash borer. Stinking-ash does not belong to the rose family, nor is it a true ash, so the plant dodges both the fire blight and emerald ash borer bullets.

Figure 4. A characteristic "shepherd's crook" on crapapple caused by bacterial fire blight. (Photo by Joe Boggs)

Be aware that some plant pathogens and plant pests have alternate hosts, so two very different plant groups may be affected by the same problem in different ways. The fungus *Gymnosporangium juniperi-virgianae* produces large, reddish-brown plant galls that sprout fungal horns on the stems of junipers. On apple leaves, the fungus produces round, lipstick-red leaf spots. The common name for this disease reflects the two hosts: cedar-apple rust. The "cedar" refers to eastern redcedar (*Juniperus virginiana*) which is a juniper, not a true cedar as indicated with the contraction used in the common name. Once again, beware of common names!

Fungi are not the only gall-makers. There are a number of insects and mites that direct the growth of plant galls, and most are highly specific to their hosts. Indeed, most are so specific the gall-maker can be identified to species based on the gall structure alone without the need to see the actual gall-maker. There are over 800 gall-making insects that are specific to oaks, and over 700 are tiny wasps belonging to the family Cynipidae. The cynipid wasp *Amphibolips prunus* stimulates plant cells in pin oak acorn caps to grow an unusual ball or plum-shaped structure that surrounds a single wasp larva. The galls are commonly called oak plum galls, or oak acorn galls, and they are only produced by this wasp on pin oaks.

Knowing your plants, and even what family and genus they are in, is a great starting point for diagnostics. This, of course, helps not just with identifying infectious diseases like fire blight and rust, but with other problems as well. Consider a yew or rhododendron growing in poorly drained soil. Knowing these plants are particularly prone to root decline and root rot in poorly drained sites helps immensely with a proper diagnosis when plant decline is evident. It should not blind you to other possibilities, but it certainly is the type of smoking gun that should be investigated.

Question 4: What do you see that looks abnormal?

Plant abnormalities are categorized in terms of "signs" and "symptoms." Signs are the actual causal agent; some part of the pathogen is visible. A fungal pathogen that causes interior rot in a tree is revealed when it produces bracket-like fruiting structures that grow out of the side of the tree. Powdery mildews reveal themselves when they produce white, powdery mycelia that cover leaf surfaces. Both the bracket-like fruiting structures and the powdery mycelia are "signs" since they are the actual causal agents for the diseases.

Symptoms result from interactions between the plant and pests, pathogens, or environmental elements (e.g. high soil pH). In other words, a "sign" is the actual pathogen while a "symptom" is what the pathogen does to the plant. Symptoms include such abnormalities as: off-colored foliage; deformed or stunted foliage; leaf spots, blotches, blisters, or scabby spots; stem dieback; stem cankers; root rot or root loss; canopy thinning; and overall plant decline.

Remember that the same symptom may be produced by multiple causes. Twisted, deformed leaves can be caused by sucking insects such as aphids, or exposure to plant growth regulator herbicides. Tiny leaf spots can be caused by a leaf-spotting fungus or bacterium, or lace bugs and mites. Yellowed leaves (leaf chlorosis) may be caused by nutrient deficiencies in the soil, or by a soil pH that makes the nutrients unavailable to the plant.

It is important to clearly consider and list what signs and symptoms are present that make you believe there is a problem in the first place. For example, are there signs of insect or mite feeding? If so, is injury from pests with chewing or sucking

Figure 5. Cedar-apple rust fungal spore horns sprouting from a plant gall caused by the fungus on juniper. (Photo by Joe Boggs)

Figure 6. These bracket-like fruiting structure of the wood-decay fungus *Polyporus squamosus* is a disease "sign." (Photo by Joe Boggs)

mouthparts? Similarly, are there signs of fungal diseases, such as the orange fungal growth of rust disease? Are leaves missing off-color, abnormally small or scorched? Is there abnormally peeling bark? Are there girdling roots — or are roots rotted in the pot or in the soil? Are there abnormal growths such as galls or discolored cankered areas on stems?

The list can be extended and extended. It is important to walk around the plant — looking at it up close and from far away — and to catalog every noticed item as you work on your diagnosis of what may possibly be multiple problems.

Finally, when considering symptoms, keep in mind that there are often a series of symptoms, known as the "symptom complex," which together helps fingerprint a particular problem. When questioning if lace bugs are a problem, check not only for flecking and yellowing of leaf tissue, but also for tarlike excrement deposits. When checking for *Verticillium* wilt on maple, check not only for leaf scorching and stem dieback but also for discolored streaking of the vascular tissue.

Figure 7. The "symptom complex" for lace bugs is illustrated by these chrysanthemum lace bugs. (Photo by Joe Boggs)

Figure 8. The thinning canopy of this ash tree indicates an overall decline in the health of the tree. (Photo by Joe Boggs)

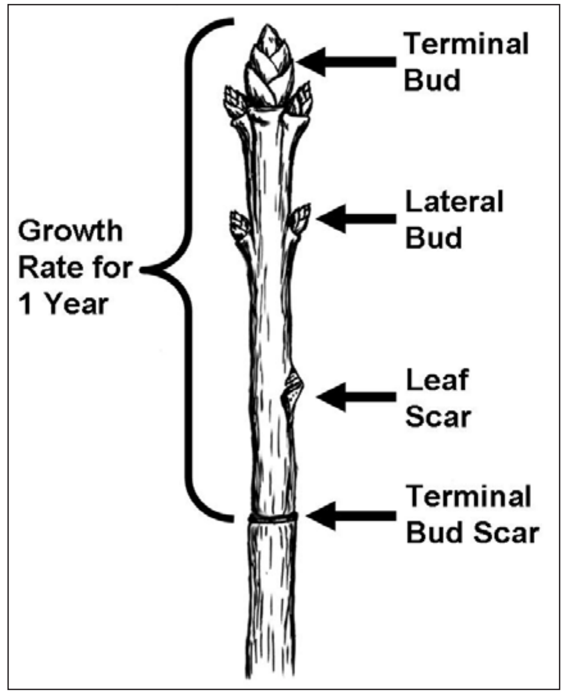

Figure 9. Annual growth rate. (Graphic drawn by Joe Boggs)

Question 5: What is the overall health of the plant?

It is a good reminder to put into perspective overall plant health. Presumably you have found something abnormal or you would not be continuing with the diagnosis, but step back for a moment to consider overall health. This helps later in terms of what you will recommend and how important various problems on the plant might be, but it also helps provide focus relative to how long problems might have been present. Consider, relative to a healthy specimen of the same plant, such questions as whether leaf size and color are normal, if the canopy is full or if the growth rate is normal.

For example, the terminal buds on many deciduous trees produce a distinct scar that delineates seasonal growth. If you measure the space between terminal bud scars on the twig, you can tell how much it has grown in recent years. It is a little tricky to know what a normal rate of growth is and whether lower than normal rates necessarily mean the plant is unhealthy. However, declining rates of growth over the past several years can be telling, and they can often even be traced to a particular event, such as installation of new sewer lines or a new driveway. Conversely, pointing out normal annual growth can also help allay fears that something major is wrong with the plant — for example, on maple when all that is found is some tarry spots on the leaves.

Question 6: What exactly do you see?

At this point, it is important to inject a "reality check" in the diagnostic process. Are you on the right track? After stepping back to consider the overall health of the plant, force yourself to step back again to reconsider in more detail Question 4: What

Figure 10. Physiological leaf scorch on maple is characterized by leaf-browning that starts along the edges of leaves, and moves inward. (Photo by Joe Boggs)

Figure 11. Diplodia (*Sphaeropsis*) tip blight of pine is characterized by browning and stunting of new shoots. (Photo by Joe Boggs)

do you see that looks abnormal? The key to diagnosis is often in such details, sometimes related to others who help with the diagnosis, such as a diagnostic lab technician or coworker in your company.

It is very important to note the pattern of damage. Is the damage on older leaves, newer leaves, or both? Is the damage only on the lower part of the plant, upper part of the plant, or throughout the plant? Do symptoms appear to be located on a particular part of the leaf? A good example of this is the difference in symptoms between maple anthracnose and physiological leaf scorch of maple.

To the casual observer, both problems involve blotchy, scorchy, brown discoloration of the leaves. However, the details are quite different. With anthracnose, caused by a fungus, the blotched areas are more of a reddish brown than a tannish brown, but more importantly, are concentrated along the leaf veins. With physiological leaf scorch, caused by excess evaporation of water from leaves due to a variety of factors, the blotches are not concentrated along the leaf veins and are typically more to the outer margins of the foliage. Knowledge of this difference in symptoms is the sort of fine-tuning that diagnosticians develop as they improve their observational and reporting skills.

As can be seen with this maple example, noticing where symptoms are occurring is critical. Diplodia (*Sphaeropsis*) tip blight of pine is characterized by browning and stunting of new growth on young Austrian, red, Scots and mugo pine shoots, in addition to dieback of this new growth (the growth farthest out on the branch). This disease typically occurs on the bottom branches of the tree first and works its way upward over the years. Compare this to the normal seasonal loss of inner needles from previous years that occur on pines. Every fall, many people become worried about the yellowing, browning, and falling needles on pine, even though loss of older needles is normal. Each evergreen species drops needles of different ages, so good plant identification and knowledge is essential. Careful observation of the details of whether the browning needles are on new or old growth is crucial for good diagnosis.

Diagnosing animal damage often depends on looking for details associated with how the animal feeds. Deer do not have upper front teeth. They have lower front teeth, and a tough pad instead of upper front teeth. When deer feed, they pinch-and-pull plant material between their lower teeth and the pad. This typically produces ragged edges rather than clean cuts on foliage, and tips of twigs may look like toothpicks because the outer bark has been pulled off. Rabbits have very sharp upper and lower front teeth and when a rabbit bites, their incisors cross at a 45 degree angle. So, they produce clean cuts that are angled at 45 degrees.

Figure 12. Deer feeding activity on hosta is often signaled by torn leaves that have tattered edges. (Photo by Joe Boggs)

Figure 13. Rabbit feeding damage is characterized by cuts made at 45 degree angles. (Photo by Joe Boggs)

Question 7: What do you see on other plants?

Now take note of the condition of surrounding plants. Are other specimens similarly affected? What is their general health? If you are looking at a grouping of a particular species, does symptom severity seem to relate to any kind of gradient of drainage or sun exposure? Trying to answer such questions often provides key clues about major environmental factors. If, for example, a number of different vegetables in a garden are all dying, it is unlikely they are deteriorating from an infectious disease since most disease-causing pathogens have limited host ranges. It is more likely that some environmental factor, such as extended flooding or poor soil conditions, is involved.

Often noticing what is occurring on overhanging plants can prevent embarrassing misdiagnoses. Scale insects, which suck sap from plants, excrete this processed sap out the other end in the form of "honeydew." Often this clear, sugary, sticky liquid becomes covered with a sooty mold fungus that simply grows on the sugary substance, rather than plant tissue itself. Calico scale is a prolific producer of honeydew. Consider what happens to the leaves of plants underlying a tree that is heavily infested with this scale insect. The underlying plants are not infested; however, their leaves become blackened with sooty mold. Of course, an effective treatment must focus on the scale infestation rather than non-infested plants with blackened leaves.

Question 8: What are the plant's site conditions?

Question 7 leads directly to a more focused examination of the site in which the plant is growing. A few key site characteristics can include everything from soil characteristics and exposure to sun and rain, to construction history and competition from other plants.

The soil type relative to drainage, extent of compaction, amount of organic matter, and acidity/alkalinity can tell a great deal about the success and failure of various plants. Poorly drained soils with poor internal aeration sooner or later result in death of *Taxus*.

Acid-loving plants often develop yellowing between the veins (or to put it more stuffily — interveinal chlorosis) if growing in alkaline soils (pH above 7) due to iron deficiency. This can be diagnostically investigated by using soil tests and even plant tissue analysis, or by simply looking at the plants on-site. If you notice rhododendrons, birches, white pines, and other acid-loving plants thriving in a location, then a diagnostician might suspect the yellowing of leaves on the similarly acid-loving pachysandra is due not to iron deficiency, but rather to other factors such as overexposure to sun.

Sun and shade exposure is also critical to the success of many plants. Japanese maples tend to thrive in protected sites, developing physiological leaf scorch in hot, sunny areas. Flowering dogwoods generally do poorly in open, hot sites (and often develop borer problems if stressed) and also in densely shaded sites where diseases, such as dogwood anthracnose, are favored. Partial shade is best for flowering dogwood.

Exposure to wind can result in desiccation of leaf tissue of broad-leaved evergreens such as rhododendron in winter and should be considered while diagnosing these plants and the extent of wind exposure. Even exposure to rain can be an important clue. Diagnosticians often miss the implication of overhangs from houses when wondering why herbaceous ornamentals near structures seem to be languishing despite adequate recent rainfall.

The effects of construction are also a factor that should be investigated relative to the site. How much soil grades were raised, the effects of bulldozers on soil compaction and root destruction, installation of sewer lines, driveways, roads, and structures all play a role in plant health, often many years after the fact. Diagnosis would be easy if raising the soil grade 6 inches during construction activity caused trees to fall over within a week or two.

The truth, however, is that this kind of stress on root systems, due to reduced oxygen concentrations for the now-buried roots, can have effects for years from the contribution to overall plant stress. Nailing down exactly how much damage is due to various factors is difficult — if not impossible — to pinpoint, but it is the job of the diagnostician to put it into as clear a perspective a possible.

Always keep an eye on plant selection when assessing site conditions. It is very difficult to modify the site once a plant

Figure 14. Black sooty mold on the surface of a magnolia leaf. (Photo by Joe Boggs)

Figure 15. Iron chlorosis on pin oak may signal a high soil pH. (Photo by Joe Boggs)

Figure 16. Soil compaction from construction equipment. (Photo by Joe Boggs)

is planted. In cases where it's "wrong plant, wrong site," your recommendation may be to replace the plant. Good plant health management means starting with the right plant in the right place.

Question 9: Who knows the most about the plant?

One of the limits of diagnosing plant problems, unlike with human medicine, is that the patients cannot talk. However, asking questions of the person who knows the most about the plant often yields the most important information of all. People who work in a diagnostic laboratory will tell you the information on the sample is often more important than the sample itself. Try to find out from them the answers to the next question.

In some cases, the person who is most familiar with the plant is not the person with the direct responsibility for managing the plant. Consider a landscape around a commercial office building. The building's owner may not be located in the building, and the company hired to manage the landscaping may only make periodical visits. Who knows most about the plants? It may be the people who work in the building. Do not overlook interviewing the people who actually see the plants on a day-to-day basis.

Question 10: When did symptoms first appear?

Although listed as #10, this is a very important question: when did the symptoms of the problem in question first become evident? Sometimes the answer is unreliable; we have all heard "it up and died overnight." We can check this out, though, by looking at annual growth and symptoms, such as long-term branch decay and peeling bark. Sometimes people do provide crucial information that helps solve the problem, such as noting that foliar collapse occurred soon after a spring frost.

Plant symptoms sometimes progress through a series of different "looks." It is helpful to consider symptom progression in the context of having a beginning, middle, and end. The oak shothole leafmining fly (*Agromyza viridula*) uses its sharp ovipositor to puncture young expanding oak leaves to cause liquids they feed upon to flow. They often produce holes in a row, and if new leaves are punctured prior to unfolding, the holes will appear as mirror images on different parts of the leaf. In the beginning, the holes are extremely small; however, they become larger as the leaves expand. In the end, they may measure over 1/2 inch in diameter. Of course, by this time, the fly is long gone.

Plant stress may also produce a progression of symptoms. However, there are two types of plant stress: acute and chronic. Acute stress is caused by an immediate event, such as flooding, drought, or defoliation by an insect pest. Symptoms are usually immediately evident and easy to diagnose since the cause is close at hand.

Chronic stress is caused by more subtle conditions such as the site problems listed in Question #8 or horticultural problems that will be covered in the next question. The effects of chronic stress are usually cumulative, meaning that the damage adds up over time to eventually produce dramatic results. A mature oak tree that has had its root system damaged or reduced by construction may take years to show the full effects, with symptoms such as a thinning crown gradually progressing towards the death of the entire tree. The tree does not "up and die overnight" — it began the slow spiral towards death when it was first exposed to chronic stress.

Question 11: What is the horticultural history of the plant?

This inquiry involves a whole series of important questions, some of which can be answered only by others, some of which you can determine from evidence at hand. For example, what is the plant's transplant history? Looking at a declining 40-foot tree can be a puzzle that is pretty easily put together when you discover the tree was transplanted two years previously. On younger plants, transplant history is often quite evident. A declining rhododendron that has branches growing out of the

Figure 17. Damage from the oak shothole leafmining fly. (Photo by Joe Boggs)

Figure 18. “Mulch mounds,” or “volcano mulching.” (Photo by Joe Boggs)

Figure 19. Late-spring freeze damage to trident maple. (Photo by Joe Boggs)

ground and is planted 6 inches deeper than the root ball grade tells a great deal about the causes of decline. Apply the axiom: “plant them low, never grow; plant them high, watch them die; plant them right, sleep at night.”

The same combination of questions to ask and clues to look for apply to horticultural practices such as fertilization, mulching, pesticide spray programs, plant hardiness, use of girdling wires and the source of plant material. You can ask about fertilization rates, but you can often find telltale signs that help ask more pointed questions, such as an excessive pile of granular fertilizer on the ground or on mulch.

Check the depth of organic mulches. The recommended amount is 2 inches to 2½ inches, although more commonly 6 inches to 8 inches (or even more) is applied, or mulch piles up over the years with reapplication exceeding breakdown. Additionally, mulch is often piled up against the trunk of a tree or base of a plant. The result of this overmulching may be the reduction of oxygen availability to feeder roots, especially on young plants, and excessive moisture retention may potentially lead to crown and root rots. Mulch mounded against the base of the crown can also provide a perfect protected location for rodents in winter, which can severely damage or kill young, thin-barked trees and shrubs.

Again, consider the always-important question of timing. An irrigation system that is present and seemingly functional may not have been working during the hottest portion of the summer, when observed damage really was caused. Conditions may be cool and non-stressful in September, but what if a large tree was transplanted on a 100 degree day in July?

Question 12: What is the environmental history?

In addition to what we do horticulturally, it is important to consider past environmental events. How harsh have recent winters been, and how does this match up to a particular plant’s hardiness range? Also, severe freezes in a given year can result in plant dieback and death well into a growing season.

Often clients think if a plant flowers normally or leafs-out normally, then all is well with regard to surviving winter damage. Sometimes, bud tissue breaks; however, early freeze damage to a plant’s cambium prevents that plant from growing beyond that initial bud break, and stems, or the entire plant, may die. These symptoms of delayed winter injury are quite common in cherries, as well as other *Prunus* selections.

Plants may also bud out and look fairly normal well into late spring and early summer, then hot weather occurs, and the underlying damage to the cambium causes dieback to occur. This type of problem again highlights the separation in time of the cause of damage and the obvious symptoms of this injury that make diagnosis such an art.

If a plant is known to have difficulty under droughty conditions, early hot, dry weather in a given season can have major effects on plants such as turfgrass and tender perennials, including *Ligularia* and *Astilbe*. Severe drought in past years should be factored into the current condition of certain drought-sensitive trees, such as beech. How a plant responds to particular additional stress depends upon its entire horticultural and environmental history.

Question 13: What does the client think the problem is?

A careful interview of the client regarding their thoughts on the problem can provide critical pieces of information that contribute to an accurate diagnosis. Remember that you are interviewing the client, not interrogating! Avoid asking “leading” and accusatory questions, such as, “Did you over-fertilize the plant?” or “Did you give the plant too much water?” These

Figure 20. Leaf scorch on dogwood caused by a summer drought. (Photo by Joe Boggs)

questions are not likely to yield useful information; they are more likely to yield an angry client.

Consider phrasing questions in a way that induces dialogue. For example, you may ask, "Tell me about your fertilization program;" or "Tell me how you water your plants." Both of these questions require more than "yes" or "no" answers, and they are not "leading" questions, meaning that you are not influencing the answer. Your goal is to simply gather more information.

Having a two-way conversation with the client will also help you learn the client's true concerns which will be very helpful in making a recommendation. Asking for their opinion on what they think the problem is makes the client a partner in the diagnostic process. A partner will be more likely to follow-through with your recommendations.

Question 14: What diagnostic tools are available?

Useful tools for diagnosis can obviously be high-tech, ranging from ever more elaborate microscopes and enzyme-linked immunosorbent assay tests for viruses and fungi in diagnostic labs to equipment from the gas company to check for gas leaks on properties where trees and turfgrass along a gas line are dying. However, for horticulturists making a field diagnosis, basic equipment can be far more manageable and less expensive. Here are six basic items:

Soil probe

This tool is useful diagnostically for soil sampling to check soil pH and nutrient levels. It can help explain, for example, foliar chlorosis due to iron deficiency on acid-loving plants like pachysandra, white pine, river birch, and rhododendron growing in alkaline soils. Probes can have more immediate diagnostic uses as well, such as determining the soil texture, or checking to see how compacted or dry soils are or the depth of mulches.

Hand lens

A good 10X or 20X magnification hand lens is useful to check for mites and small insects on plant foliage or to look for fungal fruiting bodies on leaf tissue.

Cutting tools

Good, sharp hand pruners are important for cutting small twigs to look more closely at stem and leaf problems. It is also unprofessional, to say the least, to collect a sample by stripping a twig from a plant rather than making a good pruning cut.

For larger stems, a small foldable pruning saw is also easy to carry. A knife is useful for cutting into a stem to check for discoloration of the vascular system (typical of Dutch elm disease or *Verticillium* wilt disease) or to check stems for the presence of insect borers. Although less portable, pruning poles can also be useful tools to get samples from high in a tree.

Digging tools

It is often helpful to dig a bit around the base of a plant to check for girdling roots or twine, to check where the pre-transplant root system was located, or to collect a root sample. A collapsible spade is quite handy, but sometimes blunt, wedge-like knife blades can do the trick.

Recording tools

It is important to take good notes of what you observe to later refresh your own memory and to accurately relay relevant information to others. Have a good field notebook, as well as weatherproof pens and markers. A hand-held recorder can also

Figure 21. A hand lens provides useful magnification for field diagnostics. (Photo by Joe Boggs)

Figure 22. Hand pruners are useful for collecting samples. (Photo by Joe Boggs)

be helpful if you do many field diagnoses. Finally, a camera can help convey symptoms and site characteristics for others and can be a valuable validation of the plant's condition at the time of inspection. This photographic evidence becomes especially useful if post-visit changes are made, such as the cutting down of an affected tree.

Sampling equipment

In addition to soil probes and pruners, it is always a good idea to carry along some large plastic bags for collecting samples. Avoid leaving foliage samples exposed to the heat of the sun, and if collecting soil samples for nematodes, a small cooler can be quite helpful.

Question 15: What additional resources are available?

Of course, the most important diagnostic resource you have is your experience and the collective experience of your cohorts. Also be aware of the number of reliable resources on plant identification and selection; problem identification; and specific damage by insects, diseases, wildlife, and other pests. These sources range from books to great web sites to a wide range of educational programs provided by green industry organizations and university extension services.

Furthermore, recognize that diagnostic observations in the field sometimes need verification at a diagnostic lab. These labs use microscopic examination, fungal culturing, and a wide range of tests to help confirm or deny the presence of certain problems. Take advantage of the university, government, or private diagnostic labs in your area. In addition, other laboratories specialize in different pieces of the puzzle. Examples are soil test and foliar analysis laboratories used for information on possible nutrient deficiencies or excesses, and analytical laboratories that check for chemical residues in plant tissue.

Question 16: How do I take samples?

At this point in the diagnostic process, you probably have a tentative diagnosis of the problem. You are now focusing on confirming your suspicions. Each type of plant problem can require special techniques to get the best sample back to colleagues or to a diagnostic laboratory. Following are a few hints adapted from Ohio State University Extension bulletins:

Obviously, many times you can only sample a small portion of a plant, but when large numbers of small plants are affected, collect entire plants, including roots. If 500 rhododendrons are going down, do not just send a leaf or two. Dig plants to keep roots intact rather than simply pulling the material out of the ground. Remove excess soil by gently shaking or washing with water. Do not wet leaves or stems. Wrap roots so clinging soil won't be loose in the packaging. Do not ship wet plants; let them air-dry first.

If only a portion of a plant is sampled, include the part showing symptoms. Also, when possible, collect about a pint of roots, soil and fine rootlets.

When only localized parts of a plant are affected (leaf spots, stem cankers), ship several examples of the affected parts. Stem and branch sections should include a short section of healthy tissue so the transition area between healthy and diseased tissue is included. For example, if collecting a sample to check for Verticillium wilt disease, select 1-inch diameter stem sections about 6 inches long, ideally from the area where the stem transitions between healthy and diseased tissue, rather than collecting dead stems.

If shipping, press non-woody plants or leaves on small twig between paper and put them between pieces of stiff cardboard, then place in a padded envelope. For succulent plants, samples packed in airtight plastic often decay before arriving in a lab. Place the leaves of such specimens between paper towels before packing. Use strong containers, filling spaces with shredded paper or other materials to cushion the sample in transit. Use rapid mail delivery for best results.

Question 17: What else needs to be considered?

By now, having asked all kinds of questions and in some cases consulting others or sending in samples for analysis, a good diagnostician asks for the last time, "What else might I be missing?" Question #6 provided the first "reality check" in the diagnostic process; this is the second. You should stop and reconsider everything you have learned thus far. Does it all add up to support a good diagnosis?

Emerald ash borer provides a good example of the value of stopping to reconsider everything before making a diagnosis. Prior to the discovery in 2002 that this non-native beetle was living in the United States, people were certainly aware that ash trees were dying. However, correctly diagnosing a plant problem that is not known to occur is without doubt the most difficult diagnosis to make. We tend to focus on the "known."

It was known that a number of tree-killing diseases could occur on ash, including ash yellows and *Verticillium* wilt. Ash trees were generally considered "tough trees" and they were often planted in challenging sites such as in parking lot planters, or along street curbs. It was no surprise that many died. Finding holes in these trees was also no surprise since it was well known that several native insect borers target stressed ash trees.

Reconsidering Question #4, "What do you see that looks abnormal," along with Question #6, "What exactly do you see" would have been helpful in disclosing the presence of emerald ash borer. Native borers produce round or oblong adult emergence holes; emerald ash borer produces distinctly "D"-shaped holes. Sadly, it is now known that emerald ash borer was living in the United States at least 10–15 years prior to its discovery; prior to a correct diagnosis. "What else?" should always be a nagging question on a diagnostician's mind.

Question 18: What is the diagnosis?

The last example brings us to several cruel realities of diagnosis. First, sometimes you just won't have the insight to ask the "What else?" question that starts your light bulb blinking. Second, even when you do ask the question, it may not result in

Figure 23. An emerald ash borer adult beetle. (Photo by Joe Boggs)

Figure 24. Emerald ash borer "D"-shaped adult emergence holes. (Photo by Joe Boggs)

an open-and-shut case. With emerald ash borer, diagnosticians in 2001 simply did not know that the borer should be added to the list of possible problems that could occur on ash trees.

Even if your diagnosis focuses on a well-known problem, the reality is that you are almost always somewhat uncertain as to your diagnosis. A more reasonable goal for diagnosis is to strive to come up with the best diagnosis possible while acknowledging the possibility of other factors. That being said, it is important to be clear about what you did diagnose and also, often just as importantly, about what you did not find. In reporting your diagnosis, remember to do the following:

1. Describe the symptoms you observed clearly and in detail.
2. Identify the problem or problems you think these symptoms signify.
3. Indicate how you made this connection (consulting with colleagues, references, and lab tests).
4. List what you did not find. As indicated above, what you did not find can often be critical. If you do not find Dutch elm disease or other infectious diseases, if there is no evidence of bronze birch borers or Asian long horned beetles, and if the symptoms and/or residue analysis is not suggestive of growth-regulator herbicide injury, this may go directly to the heart of your client's greatest concerns.
5. Put diagnoses into perspective and provide recommendations.

Question 19: What is the significance of the problem?

After making a diagnosis, it is important to put the suggested problem into proper perspective relative to overall plant health. For example, most pest and disease problems are insignificant relative to plant health. Beech blight aphids have a nasty sounding name, their white woolly bodies may cover beech branches, and their honeydew may rain down to cover underlying sidewalks with sticky goo; however, they cause little harm to their host tree. Powdery mildew of lilac occurs every year and seems to cause little effect relative to overall lilac health and survivability. Most of the mite and insect galls on plant leaves are quite fascinating but cause negligible effects on plant health.

However, here you need to be a good communicator, to understand your clients and listen to their concerns. Just because a problem will not affect plant health, or in your opinion, affect aesthetics significantly, does not mean your client agrees. In some sense, plant problems are in the eye of the beholder. While powdery mildew of lilac may be irrelevant to plant health in one landscape, it may matter a great deal to a client who will simply take his or her business elsewhere if you do not do something

Figure 25. Beech blight aphids. (Photo by Joe Boggs)

Figure 26. Powdery mildew of lilac. (Photo by Joe Boggs)

about the problem. And it certainly matters to a garden center displaying lilacs in its sales area.

Question 20: What are my recommendations?

Finally we've reached the all-important decision of what you recommend to fix the problem. First, remember that sometimes "doing nothing" is the best recommendation. If the problem is trivial and the customer is not concerned about it, then simply letting the client know that the maple bladder gall mites are insignificant and nothing needs to be done is a good recommendation.

Second, sometimes nothing can be done to make the plant recover. In such cases, often the best recommendation relates to considerations for the timely removal and replacement of the plant.

Third, when action recommendations are given, always remember the crucial element of proper timing. If you diagnose Diplodia (*Sphaeropsis*) tip blight of pine in July, it is important to specify that any chemical to prevent new infections be applied the next spring since fungicides applied at any other time will be of no use for disease control.

Fourth, recommendations should be made within a range of proper expectations. A good example is of pin oak planted in highly alkaline soil at an institutional site. Years later, the root system has grown out beyond the original root ball and amended soil into the alkaline soil. The tree begins to show symptoms of iron chlorosis, starting with interveinal yellowing (chlorosis). After years of this, the problem becomes more severe, with leaf necrosis (browning) and stems dying back. Everyone begins to notice, and it is agreed that something must be done. Experts are called in and asked for diagnosis and recommendations. With reasonable certainty, buttressed with clear-cut symptoms, as well as soil and foliar analysis tests, iron deficiency is diagnosed.

However, recommendations that actually solve the problem are another matter. There are a lot of possible treatments, ranging from trunk implants of iron to the use of chelated iron fertilizers in the soil to injections of iron in the roots. All are problematical relative to a long-term cure of the problem, especially if the situation is severe. If you make it seem like your recommendations are absolute, then you put the grounds maintenance people who have to act on your recommendations in jeopardy of being deemed incompetent once treatments fail.

Finally, the art and science of professional plant diagnostics are often overlooked by those with instant answers to every problem. Beware of those easy answers, especially if the diagnostician did not even ask a question. Diagnostics requires good detective and communication skills, and plant diagnosticians need a thorough knowledge of horticulture, botany, entomology, and plant pathology. No one can ever be the perfect diagnostician, and there is always room to improve and grow, to make and correct mistakes.

Always remember that with plant diagnostics, as with human medicine, it is useful to cultivate humility. The first surefire rule of plant diagnostics is nothing is surefire.

For detailed information on each of the IPM strategies, see the fourth fact sheet in this series, "Keeping Plants Healthy: An Overview of Integrated Plant Health Management" (PP401.04).

Introduction to Plant Disease Series

PP401.01: Plants Get Sick Too! An Introduction to Plant Diseases

PP401.02: Diagnosing Sick Plants

PP401.03: 20 Questions on Plant Diagnosis

PP401.04: Keeping Plants Healthy: An Overview of Integrated Plant Health Management

PP401.05: Viral Diseases of Plants

PP401.06: Bacterial Diseases of Plants

PP401.07: Fungal and Fungal-like Diseases of Plants

PP401.08: Nematode Diseases of Plants

PP401.09: Parasitic Higher Plants

These fact sheets can be found at OSU Extension's "Ohioline" web site: http://ohioline.osu.edu. Search for "Plant Disease Series" to find these and other plant pathology fact sheets.

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