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In This Issue

Elemental Deficiencies: You get what you test for!

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The maintenance of plants in the urban landscape is demanding at times. The many challenges that imperil trees in the urban forest are numerous and increasing. Plant Health Care requires education, experience, and credible resources to make informed decisions on plant interventions. These skills are needed especially for understanding and recognizing nutritional requirements as well.

Symptoms of chlorosis on a maple leaf

Trees can't really tell us what is wrong, so, we rely on the expression of symptoms and identification of signs to differentially diagnose the causal agent or agents. Our first, and most intuitive diagnostic step is typically through visual associations when we notice a plant with a less than healthy presence. This includes a comparative recognition of appearances considered typical against atypical representations of the plant. Commonly, this results in identifying leaf discoloration such as yellowing of the live tissue or specific chlorotic patterns and that is all we get for nutrient deficiencies, and it just isn't enough. Often leaf tissue analysis detects fertilization problems within an existing program. Someone may be applying a fertilizer product, but the plant may not be responding as expected which indicates availability issues. Trees and their growing environment differ even within the same site and cannot be managed collectively and expect results. Individual cohorts may require specific PHC needs.

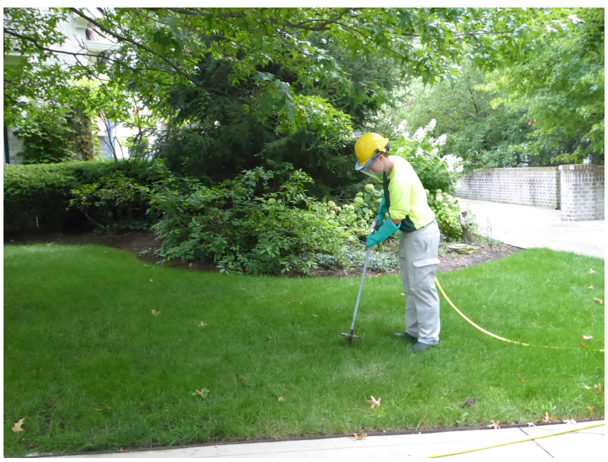
The PHC predicament is simply "Are you capable of making an informed decision with a visual identification regarding nutrient deficiencies? Simply, the answer is no. Responsible, ethical plant health care requires critical thinking which engages the best resources and application of the solution. First, this requires identifying the appropriate testing methodology for nutrient deficiencies and pH as well as an understanding of how the law of minimums can apply to plant health and nutrition.

Decline can be attributed to many factors, especially abiotic issues.

When agricultural scientists centuries ago began to realize mineral elements in a plant were taken up from the soil in which the plants grow, it was a logical step to suggest that chemical analysis of plants could be used as a means of assessing the nutrient supply of the soil. At the time it also appeared reasonable to suggest, as von Liebig did in the last century in his Law of Restitution. This premise suggests that plant analysis could be used to determine the quantities of nutrients removed from the soil by a crop and, therefore, the amounts needed to maintain the supplying power of the soil. Justus von Liebig's **Law of the Minimum** states that yield (growth) is proportional to the amount of the most limiting nutrient, whichever nutrient it may be. From this, it may be inferred that if the deficient nutrient is supplied, yields (growth) may be improved to the point that some other nutrient is needed in greater quantity than the soil can provide, and the Law of the Minimum would apply in turn to that nutrient. (*van der Ploeg, R., Böhm, W. and Kirkham, M. (1999), On the Origin of the Theory of Mineral Nutrition of Plants and the Law of the Minimum. Soil Sci. Soc. Am. J., 63: 1055-1062).*

Basically, all plant growth is regulated by its greatest need or the nutrient in the shortest supply regardless of the abundance of other nutrients. Some soils have the necessary essential elements but, supplementation may be needed to overcome deficient soils or enhance growth.

Various factors affecting availability include soil type, pH, cation exchange capacity (CEC) and water holding capacity (WHC). Understanding soil properties allows us to better diagnose for a more prescriptive solution to deficiencies often found in urban soils.



Supplemental nutrition should be prescriptive based on proper testing.

It is estimated that less than 2% of a tree's materials are derived from essential elements taken from a soil. Failure to obtain all essential items lead to primary deficiencies, secondary symptoms, and metabolic dysfunction *(White, P. J., & Brown, P. H. (2010). Plant nutrition for sustainable development and global health. Annals of botany, 105(7), 1073–1080).*

The formula for maintaining a healthy, sustainable tree depends upon specific application of essential elements. Essential elements in excess or inadequacies can lead to minor health issues at least, or devastating failure and even death in worst cases.

Soil analysis is helpful in formulating and improving a fertilization program because soil testing measures organic matter content, pH, and extractable nutrients. Soil analysis is particularly useful when conducted for several consecutive years because trends can be observed. However, plant health care professionals cannot rely on soil analysis alone to formulate a fertilizer program or to diagnose a nutritional issue in the landscape.

Diagnosis of potential nutritional problems should be a common practice. Quantifying nutrients in soils and trees eliminates guesswork when adjusting a fertilizer program. Elemental deficiency or surplus causes trees to grow poorly or affects them negatively in other ways. However, soil tests aren't the only or singular option for nutrient deficiencies. Soil testing and leaf tissue analysis do not assess all the same factors, so care must be taken to choose the correct test when diagnosing nutritional concerns.

Leaf tissue analysis is a very useful tool to detect problems more specifically and adjust fertilizer programs for trees and shrubs because leaf nutrient concentrations are the most accurate indicator of any plant nutritional status. Considerable research involving leaf testing has established its reliability as a management tool, but sampling guidelines should be followed precisely to ensure that analytical results are meaningful.

Leaf tissue analysis tests all the factors which influence nutrient availability and uptake. Tissue analysis shows the relationship of nutrients to each other as well. For example, K deficiency may be from a lack of K in the soil or from excessive Ca, Mg, and/or sodium (Na). Similarly, adding N when K is low may result in K deficiency since the increased growth caused by N requires more K. There are many nutrient interactions when it comes to prescriptive nutrition programs. Effective PHC requires knowledge of these interactions to prevent compounding problems. This could be considered similar to drug interactions within people and their prescriptions.

Comparatively, Leaf analysis is a useful tool to detect problems because leaf nutrient concentrations are the most accurate indicator of crop nutritional status. Leaves reflect nutrient accumulation and redistribution throughout the plant, so the deficiency or excess of an element in the soil is often reflected in the leaf.

Soil tests are quite useful for pH, organic matter content and other qualities. Relative to nutrition, soil tests primarily measure extractable elements present in the sample. However, it doesn't measure the total amount of nutrients present nor the quantity actually available to the tree.

- Finally, a sampling or testing program can be most effective if conducted annually, especially on problem plantings. Leaf tissue testing is valuable for all elements. Soil testing is most useful for consideration of pH, P, Ca, Mg, and Cu concentrations. A key point is visual identification tools are unreliable because virtually every deficiency reveals similar expressions of chlorosis. There are some key points to remember when sampling for tests to get best results. Pesticide spray residues on leaf surfaces affect sample results be sure to wash leaves for accurate analysis. Especially avoid sampling recently treated trees.

- Interpretation of leaf and soil tests should be used to make fertilizer or supplement decisions. A broad-spectrum or "shotgun" approach is never accurate, less effective, and often not economical either. Wise use of the results allows optimal health and growth and minimizes environmental impacts and reduces fertilizer waste with inaccurate applications.

Red Headed Flea Beetle Can be a Beast to Manage in the Nursery

(Cliff Sadof, csadof@purdue.edu)

Over the past 15 years the red-headed flea beetle, *Systena frontalis* has become an important pest in Indiana nurseries. Adult beetles feed on leaves of a wide variety of popular shrubs like hydrangea, azaleas and rhododendrons, bottlebrush, weigela, Virginia sweetspire, summersweet, roses, and hollies. Although the leaf feeding rarely harms plant health, plants with significant numbers of chewed leaves are often too unsightly to sell to customers. As such this insect is emerging as one of the most important insect pests in the nursery industry throughout the United States.

Adult red headed flea beetles feed by scraping or chewing through leaf tissue of young tender leaves.

Adult red headed flea beetles feeding on this hydrangea caused too much defoliation to allow it to be sold.

Virginia sweetspire is one of many plants attacked by red headed flea beetles.

Red headed flea beetles thrive in the moist conditions of container plants in nurseries. Eggs overwinter in soil and hatch in spring. Creamy white larvae hatch from eggs and are easily found at the edge of moist root balls in container grown plants. Adults emerge from soil when inkberry holly is in bloom. A second generation of larvae present in mid-summer become the adults that lay the overwintering eggs in soil in late summer. We have seen all three stages in container grown plants in mid-summer. A third generation is likely in Indiana container grown nurseries.

Larvae(left) and pupae(right) can be found in pots of infested plants, but rarely damage the root system. Photos by Matt Bertone North Carolina State University.

Nursery grown plants can be difficult to protect. Although injury can be reduced by a regular foliar application of insecticides, the level of protection is not always complete. I conducted a trial in Indianapolis in 2021 to try to control this pest by spraying plants every two weeks. I started the trial when I saw the first beetles feeding on limelight hydrangeas on May 24 at 460 Growing Degree Days base 50 (GDD_{50}). Every insecticide I used, protected plants for the first month (June 24 1090 GDD_{50}). After this point adult beetles became plentiful as adults emerged from containers in the nursery. By July 5, (1375 GDD_{50}) damage became unacceptable on most of the commercially available treatments. By July 28, none of the commercially available treatments provided protection.

Best Practices for Managing Red Headed Flea Beetles. Research conducted on the best approach protecting plants has been summarize in a recent article by Danny Lauderdale of North Carolina State University. Highlights of this article (available at this link) are as follows:

- *Use Foliar Sprays to kill adults.* A wide range of insecticides can be applied to provide acceptable control. These must be sprayed when adults are first seen. This can start around 500 GDD_{50}, or earlier if nursery pots and beetles winter in protected structures. Sprays may need to be applied weekly if you continue to see significant numbers of live beetles on your plants during weekly inspections. Of the 15 compounds he lists that provide efficacy, Sarisa, Pradia, Acephate 97UP and Duragard ME are among the more effective based on his groups observatins and what I have seen in Indiana. Be sure to rotate classes of insecticides to avoid developing resistance and exceeding seasonal limits to the use of each pesticide. Although repeated applications are needed, many growers find it easier to apply than drenching or applying granules to pots.
- *Use soil drenches or granular applications to kill larvae in pots.* Applications of neonicotinoid insecticides when timed just before the beetle eggs hatch into larvae in the growing containers (212 GDD_{50}) can provide excellent control. The most effective soil drenches included Acephate 97 UP, Arena 50 WDG (clothianidin), Coretect (imidacloprid), Discus NG(Imidacloprid+ bifenthrin), Flagship 25 WG (thiamethoxam), Tree and Shrub 2G(imidacloprid), Imidacloprid 2F, Marathon 1G, and Marathon II, Safari 20 SG, Tristar 8.5 SL, Azatin O, and Duraguard ME. While this can be helpful many growers find it quite time consuming to drag hose or apply granules to each pot.
- *Incorporate imidacloprid granules into potting mix*. Using Mallet 0.5 G as his source of imidacloprid in April, plants had < 10% damaged leaves through mid August. See this link on soil incorporation for details.
- *Rotate crops*. Do not put susceptible plants in the same area every year. Swap out tender leafed plants with some potted conifers to avoid buildup of pests in the same area.
- *Don't let pots have a birthday on your farm*. Plants in the nursery for more than a year can build up populations of flea beetles in containers that you will have to contend with the next year.

Additional Resources:

Video:
https://twitter.com/cliffsadof/status/1415385964286025729?s=21

Video caption: Watch the red headed flea beetle jump into flight! (Video by Layton Rosen)

Acknowledgments.

Thanks to Danny Lauderdale for providing an update on his research and Richard Marsh who let me conduct trials at Behob's Nursery. After he helped me drag the hose so I could use his sprayer to hand drench a bay of nursery pots I now know exactly why growers find this process to be time consuming and costly.

All of the Galls in the Landscape

(John Bonkowski, jbonkows@purdue.edu)

Figure 1. Galls easily visible in the canopy of plum tree in early spring. All Photos from PPDL unless noted.

Galls are gnarly-looking problems for plants and now is the perfect time to be looking for galls on woody ornamentals in the landscape. Without their leaves, these abnormal growths on branches can be easy to spot as you look through the open canopy (Fig 1). There are many different types of galls or gall-like structures caused by various organisms, including arthropods, nematodes, bacteria, fungi, and even plants themselves. A gall is a mass of swollen plant tissue induced by growth stimulating substances produced by the causal organism. Galls may act as a shelter and food, in the case of insects and nematodes; or might be composed of undifferentiated plant tissues leading to a large mass that expands overtime. Depending on the cause, the effect of galls on plants can range from mere nuisance to something that saps energy and causes dieback and decline. Thankfully, the most common galls cause little damage.

Insect and mite gall-makers often produce galls on foliage leading to swollen structures littered across the leaves. These can be colorful, like the bright pink-red maple bladder gall (Fig 2), but often many of the galls are similar in color to the leaf, like the hackberry nipple gall (Fig 3). Leaf galls can cause defoliation if they become highly concentrated, but this does not usually affect plant vigor unless trees or shrubs are repeatedly defoliated in successive years. Some insects, like the wasp that causes horned oak galls (Fig 4), can cause galls to develop on branches. Severe infestations can lead to branch dieback, but this is infrequently the case. Management of arthropod galls can be difficult due in part to their complex life cycles and the fact that they live the majority of their lives within the gall and are protected from insecticides. Removing infested leaves and pruning stem galls can remove the insects, but it can take horned oak galls two to three years to become noticeable. Once holes are observed in the galls, the pests have already flown the coop and management is no longer needed (Fig 5).

Figure 2. Pink and Green bladder galls developing on maple foliage.

Figure 3. Hackberry nipple gall developing on the underside of the leaves.

Figure 4. Horned oak gall with characteristic horns protruding from the swollen branch.

Figure 5. Old horned oak gall with visible exit holes for mature wasps.

Figure 6. Root-knot nematode galls in the root system of soybeans. Similar galls can develop in the roots of woody plants as well.

Nematode gall-makers make up a very short list, but include some of the most damaging pests in agricultural production. Root-knot nematodes (*Meloidogyne* spp.), as the name implies, causes galls in the roots which requires a root sample or uprooting the plant to diagnose (Fig 6). Symptoms you can see above ground include general decline, stunting, chlorosis, and nutrient deficiency symptoms – essentially any type of root damage can look similar to a nematode infestation. Thankfully, root-knot nematodes are not very common in the landscape, but they do have a very wide range of hosts they can attack – over 3000 plant species: Abelia, boxwood, barberry, dogwood, Gardenia, holly, rhododendron, rose, willow, lilac, peach, and Weigela, to name a few. The biggest issue, once present, is knowing what to plant in that spot. Excavating the soil, solarization, and chemical applications are not likely to remove or kill the majority of nematodes and they will persist for many years. Planting tolerant, resistant, or non-host plants in infested spots will reduce the potential for damage in the future. Movement of soil or infested plants will spread the nematode, so if transplanting or dividing perennials, be sure to check the roots out if they don't appear as healthy as you hope.

Fungal gall-makers can infect both green and woody material. Some fungi, like *Phomopsis*, might cause large spherical knots to develop on branches, ranging from the size of a pea to larger than a softball, while others, like *Apiosporina*, causal agent of black knot, can cause galls to form along the length of a branch (Fig 7). Often these structures are irregular in shape and have many cracks across their surface. Rust fungi can cause galls in twigs that produce characteristic rusty-orange spores like cedar-quince rust on hawthorn (Fig 8) or horns like cedar-apple rust on juniper (Fig 9). Gall formation on smaller branches can lead to dieback, but galls on larger branches can lead to plant decline. Galls may not live to the full life of the tree and may die after a few years on a given branch, but the branch may still yet live. Pruning galls out of the canopy can reduce the potential inoculum for future infections and can reduce the drain on the plant.

Figure 7. Black knot galls on plum; sporulation present is likely a different fungus growing on the gall.

Figure 8. Right: Active and sporulating gall of cedar-quince rust on hawthorn; Left: old and spent gall.

Figure 9. Telial galls produced by cedar-apple rust on juniper. Gray and black colored galls are old and spent while the brown galls with orange horns are currently active and producing rust teliospores.

There are two main bacterial gall-makers: *Rhodococcus fascians* and *Agrobacterium* spp. *Rhodococcus* does not typically cause galls in woody plants, but can cause "leafy galls" in herbaceous plants. This type of symptom is a dense concentration of shoots, similar to witches' broom symptoms in trees, where leaves are packed together on one side of the plant (Fig 10). This can look like a gall, but is comprised mostly by leaves. The other bacterium, *Agrobacterium*, causes the classic disease crown gall, which can infect over 600 plant species (Fig 11, 12)! Galls can form on roots or the crown and trunk of many plant species, but aerial galls can form on branches of some woody plants, including roses, poplar, willow, and Euonymus. Both of these pathogens do not typically kill the host that they infect, even if growing over the majority of the crown, but it can reduce plant vigor and make them unsaleable. Bacteria enter the plant through natural openings and wounds, so often they are allowed entry by mechanical damage of some sort to the roots (pest feeding injury, frost heaving, damage at planting/propagation) or trunk. If propagating your own plants, be sure to sanitize your tools between plants to avoid spreading a pathogen, especially if you see a gall.

Figure 10. Symptoms of shoot proliferation or “leafy gall” caused by Rhodococcus fascians.

Figure 11. Symptoms of crown gall on Anthemis growing in pots.

Figure 12. Very large galls caused by Agrobacterium tumefaciens on potted rose.

Plants can develop gall-like growth that is not directly associated with a pathogen or pest. Swollen areas can develop on certain plants when subject to growth regulator herbicides, like honeylocust and arborvitae (Fig 13), but trees develop burls commonly both in the landscape and in natural settings (Fig. 14). Burls are an overactive production of callus tissue by the tree to some kind of stress, including physical injury or initial attack by an insect. Burls should not be removed as this will cause significant damage to trees and they are not really causing any harm.

Figure 13. Injury associated with growth regulator herbicide exposure in honeylocust (left) and arborvitae (right).

Figure 14. Burls developing on Redwoods in CA. Photo credit: David Stephens, Bugwood.org

There are so many varieties of galls, it can be difficult to keep track of or even identify them. Easiest way to find a gall is to look for a hackberry tree, which always has nipple galls, or by looking for an Oak. Oaks seem to have the longest list of gall-inducing insect pests out there. Having an idea of what kind of gall is present can help you figure out how to manage the causal agent, if it even needs management, and what other plants it might attack in the surrounding landscape.

For additional information on some of the pests listed here, please see the following links:

Insect galls
https://extension.entm.purdue.edu/publications/E-56/E-56.pdf

Rusts of landscape plants
https://www.extension.purdue.edu/extmedia/BP/BP-137-W.pdf

Black Knot
https://www.purduelandscapereport.org/article/black-knot-disease/

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