Chapter 5

CHAPTER 5

Diagnosing Plant Damage

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Diagnosis of plant problems is often a very difficult task since there can be many different causes for a given symptom, not all of which are pathogenic organisms. Soil nutrition and texture, weather conditions, lighting and many other environmental and cultural conditions influence the overall health of a plant. Insect damage can sometimes be confused with plant diseases caused by microorganisms or abiotic factors. Knowing a complete history of the plant is essential to making an accurate diagnosis. Also, a plant specimen should be in the early stages of disease-development when it is examined in order for an accurate diagnosis to be made. Once it has decayed, secondary organisms invade the tissue and evidence of the primary pathogen is often obscured.

For these reasons, it is difficult to construct a foolproof key for the diagnosis of plant problems. Even with the necessary laboratory equipment at one's disposal, it is often difficult to determine the exact cause of a plant's problem. The following pages provide an aid to diagnosing some of the common problems of urban plants. This chapter was constructed for Master Gardeners to help solve consumers' plant problems -- it is not meant for diagnosis of commercial production problems or for use by laboratory diagnosticians. The information provided is by no means comprehensive and other resources will be needed for many of your diagnoses. *The Ortho Problem Solver* is particularly useful as it contains color pictures. Other references are listed at the end of this chapter.

This chapter should help you, as a Master Gardener, ask the right questions to determine the cause of the problem or, at least, to narrow down the possibilities. For example, since both dry weather and excess fertilizer can cause marginal leaf burn, you would want to ask the grower about recent rainfall in the area and fertilizer application. Or, since wilt can result from both dry and waterlogged soil, you would want to ask about rainfall and how well the soil drains. In many cases, you will not be able to determine what caused the problem, but if you can narrow down the possibilities and mention these when you send the sample to a diagnostic laboratory, you will save the diagnostician a lot of time.

The chapter describes a systematic approach to diagnosis.

The following is a list of suggested questions to ask a grower when you are attempting to diagnose a problem.

Questionnaire for the Diagnosis of Plant Problems

Compiled by Charles H. Williams, Extension Specialist, Ornamentals

Usually when definite reasons can't be given for the poor growth or death of plants, it is often because some facts have been overlooked. Although these facts may seem minor, they all help. The following checklist is designed to assemble this information. Because these questions may direct you to areas you have overlooked, when you answer them you may be able to diagnose the problem, the cause may be due to insects, diseases, the plant's environment or certain cultural practice.

I. General History

1. Name and address of inquirer ______________________________
   ______________________________ Phone No.______________
2. Kind of plant (Botanical & Common Name) ______________________________
   Variety or cultivar______________ Approximate age of plant______________ Height_____ft.;width_____ft.
3. When was the problem first noticed this year? ______________________________
   Has the trouble appeared in previous years? ______________________________
4. Has the plant recently been transplanted? When? __________ Month __________ Year __________
5. Is the plant considered winter hardy for your area? __________
6. Are other plants of the same kind nearby? __________ How near and what it their condition? ____________
   ____
7. Are there other types of plants nearby which are also affected? ______________________________
8. Has the plant or nearby plants been sprayed or dusted for disease or insect control? ____________
   If so, when and with what? ______________________________
9. Have herbicides or any turf "weed and feed" materials been used in the vicinity? ____________
   How near and when? ______________ ______________________________
   What materials? ______________________________
10. Is there any evidence of mechanical injuries from lawn mowers, automobiles, machinery, heavy pruning, people, animals or faulty planting? ______________________________
11. Was the plant planted or treated by professional tree experts or a landscape maintenance firm, etc. ________
    If so, when and with what? ______________________________
12. Is the plant shaded by buildings, plants or other objects for the whole or part of the day? ____________
13. Is the plant in an exposed location for sun and wind? ______________________________
14. If the plant is near a building, does it primarily face north, south, east or west? ____________

15. Describe the care given the plant in question for the past 2 years.

    A. Fertilizer (kind and amount; foliar or soil application) ________________________________

    B. Irrigation (method and frequency) ________________________________

    C. Pruning ________________________________

    D. Any other practice or treatments? ________________________________

16. Comment on unusual weather conditions. (Extreme temperatures, late or early frost, heavy wind, hail and ice storms, drought periods, excessive rainfall or flooding)
    Present season: ________________________________
    Previous season: ________________________________

17. Do cement, asphalt or other types of pavement occur near the plant? __________

    What type? ______________ How near? ______________ How long has it been there? ______________

18. Are there gas, water, steam, sewer or other pipes or conduits in the ground near the plant or has anything leaked near the plants? ________________________________

19. Has the plant been exposed to salt used for ice control along a street or highway or along walk ways? _____
    (A salty mist stirred up by auto traffic can cause foliar damage to conifers. A similar problem occurs along seacoasts following storms.)

20. Soil in which the plant is growing.

    A. How deep is the surface soil above rock, hardpan or subsurface layers of soil? ____________________

    B. Is the soil primarily clay? ______________, loam? ______________ ,sand? ______________

    C. What is the internal drainage of the site? Good ______________ Poor ______________

       Excessive ______________(Good, poor or excessive internal drainage may be determined by the rate at which water disappears from a test hole. A hole may be dug to a depth of 3 feet, filled with water and a record kept of the time required for the water to disappear. Fill the hole with water 3 times and record the time of disappearance after each filling. If water remains in the test hole one or more days, drainage is poor and in need of improvement. If water drains away repeatedly in less than three minutes, drainage is excessive.)

21. Has a soil analysis for pH, major elements, and total soluble salts, etc. been done lately for the area? _____

22. Have the roots around the plant been disturbed by digging or has the level of soil been raised or lowered by filling or grading operations? ____________ If so, when and what was the change of level? ____________
    ____

23. Is there grass or other plants growing over the roots of the affected plants? ________________________

24. What mulch or winter protection practices were carried out? ________________________________

25. Has anything been dumped or accidentally spilled in the area? ________________________________

26. Has any unusual activity taken place in the area recently? ________________________________

II. Description of Trouble

Foliage (leaves, needles)

1. Off color? (Yellow, brown spots, etc.) ______________Describe ______________________________________
   ____
2. Symptoms appear on upper leaf surface? ____
   Lower leaf surface? ____
3. Edges of leaves brown? _________________________ Edges of leaves tattered? _________________________
4. Deformed? (galls, twisted, rolled, blisters, callus, etc.) ____
   Describe ____
5. Leaves wilted? ____
6. Partially devoured by insects? (Holes, leaf mines, leaves chewed on peripheral or interveinal) _____________
   Collect or Describe ____
7. Any foreign substance noted on surface? ______________Describe ___________________________________
   ____

Twigs

1. Off color? ______________ Describe ____
   ____
2. Deformed? (Swollen, lesions, cankers, galls, etc.) ______________Describe __________________________
   ____
3. Bark split? ____
4. Dark or colored streaks in wood under bark? ____
5. Channels in wood or under bark? ______________ Describe _______________________________________
   ____
6. Twig girdled by insects, old label, or price tag? ____

Flowers

1. None developed ______________________________
2. Off color (spots on petals, etc.) __________ Describe ____
3. Deformed? ___________________________ Describe ____
4. Chewed by insect? ____

Fruit (berries, pods, cones, etc.)

1. None formed ______________________________
2. Off color? __________________________ Describe ____
3. Deformed? _________________________ Describe ____
4. Chewed upon or hollowed out by insect? ___________ (Describe insect as caterpillar, maggot, grub, beetle, etc.) ____
5. Failed to mature or dropped too early? ____

Trunk, Branches, Roots

1. Oozing sap, flow of resin, or holes with "sawdust" noted? _____________ Describe ___________________
____
2. Dark streaks in wood under bark? ____
3. Discolored bark? ____________________ Swollen? __________________________________ Constricted?
4. Bark split, cracked or separated from wood? ____
5. Evidence of insects under bark? _____________ (Remove dead bark and determine extent of injury.) (Collect insect specimen.) ____
6. Any foreign substance on bark? ________ Describe ____
7. Any unusual growth on main stem at or just under soil line? ______________________________________
8. Are some roots exposed or observed to wrap around others? _____________________________________
9. Was the container, burlap, wire basket, trunk wrap, etc. removed at time of planting? _________________
10. Upon digging, does the root system of the affected plant:

    A. appear to be similar to "normal" plants of the same species? ________________________________

    B. have any lesions or growths on it? ____

    C. show evidence of rot, discoloration, or symptoms of the outer root tissue separating from the inner core, etc. ____

Additional Comments, Observations, Sketches, etc.

A Systematic Approach to Diagnosing Plant Damage

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I. Define the Problem

- **Plant Identification and Characteristics - Growth and Appearance of the Identified Plant - Normal? - Abnormal?**

  Determine if a *real* problem exists. It is essential that the plant be correctly identified (genus, species and cultivar or variety) so that the *normal* appearance of that plant can be established either by personal knowledge or utilizing plant reference books. Many horticultural plants, or structures on those plants such as fruit-seeds, lenticels, etc. may appear to be abnormal to the person who is not familiar with the specific plant. For example, the ‘Sunburst’ honey locust might appear to be suffering from a nutrient deficiency because of its chlorotic yellow-green leaf color, but it was selected because of this genetic characteristic ... it is not abnormal for this plant. Therefore, it is not a problem.

  Always compare the diseased plant with a healthy or normal plant, since normal plant parts or seasonal changes sometimes are mistakenly assumed to be evidence of disease. Examples are the brown, spore-producing bodies on the lower surface of leaves of ferns. These are normal propagative organs of ferns. Also in this category are the small, brown, club like tips that develop on arborvitae foliage in early spring. These are the male flowers, not deformed shoots. Small galls on the roots of legumes, such as beans and peas, are most likely nitrogen-fixing nodules essential to normal development and are not symptoms of root-knot nematode infection. The leaves of some plants, such as some rhododendron cultivars, are covered by conspicuous fuzz-like epidermal hairs. This is sometimes thought to be evidence of disease, but it is a normal part of the leaf. Varieties of some plants have variegated foliage that may resemble certain virus diseases. These examples illustrate the importance of knowing what the normal plant looks like before attributing some characteristics to disease.

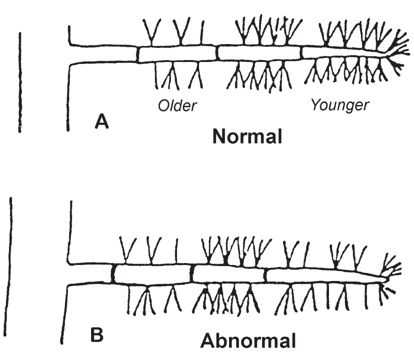
  In describing the plant “abnormality”, distinguish between symptoms and signs: Symptoms are changes in the growth or appearance of the plant in response to living or nonliving damaging factors. Many damaging factors can produce the same symptoms; symptoms are not definitive. Signs are evidence of the damaging factor (pest or pathogen life stages, secretions; mechanical damage; chemical residue; records of weather extremes or chemical applications; damage patterns). Patterns of damage often provide excellent diagnostic clues.

- **Examine the Entire Plant and Its Community**

  In defining a plant problem, it is essential to determine the *real* primary problem. There are foliage symptoms that may occur due to root damage. The primary problem would be root damage, not chlorosis of the foliage, -examine the roots. In general, if the entire top of the plant or entire branches are exhibiting abnormal characteristics, examine the plant downward to determine the location of the primary damage.

  Some pathogens and insects as well as nonliving factors are only damaging if the plant has been predisposed by other primary factors. For example, borers generally only attack trees that are already predisposed to moisture or other physical stress. Premature dropping of leaves by foliage plants (i.e. *Ficus benjamina*) and of needles by conifers frequently causes alarm. Evergreen plants normally retain their leaves for 3-6 years and lose the oldest gradually during each growing season (Figure 1). This normal leaf drop is not noticed. However, prolonged drought or other stress factors may cause the tree as a whole to take on a yellow color for a short period and may accelerate leaf loss. If the factors involved are not understood, this often causes alarm. The leaves that drop or turn yellow are actually the oldest leaves on the tree, and their dropping is a protective mechanism which results in reduced water loss from the plant as a whole.

Figure 1.
***Normal vs Abnormal* Needle Drop or Leaf Drop from Evergreens.**



Nondeciduous plants normally retain their leaves or needles for several years, but eventually they fall. This drop is usually gradual and production of new leaves obscures loss of older leaves.

A. **Normal** - If drop is confined to older leaves, alarm is unnecessary because it is a normal response to a condition of stress (e.g. drought). Unfavorable growing conditions, such as drought, may accelerate leaf fall so that it becomes apparent and of concern.

B. **Abnormal** - If newly produced leaves are lost, it is a problem. Drop of current year's leaves may result from pathogen or insect attack or from chemical deficiencies or toxicities.

II. Look for Patterns

Here is where we start making the distinction between living and nonliving factors that cause plant damage.

- **Nonuniform Damage Pattern (*living Factors*) vs Uniform Damage Pattern on Plant Community, Plant, Plant Part (*nonliving Factors*).**

  Living Factors: There is usually no discernable widespread pattern of damage. Living organisms generally produce no uniformly repeated pattern of damage on a planting (Figures 2-4). Damage produced by living organisms, such as pathogens or pests, generally results from their using the plant as a food source. Living organisms are generally rather specific in their feeding habits and do not initially produce a wide-spread, discernable damage pattern. Plants become abnormal: Tissues are destroyed, become deformed, or proliferate into galls.

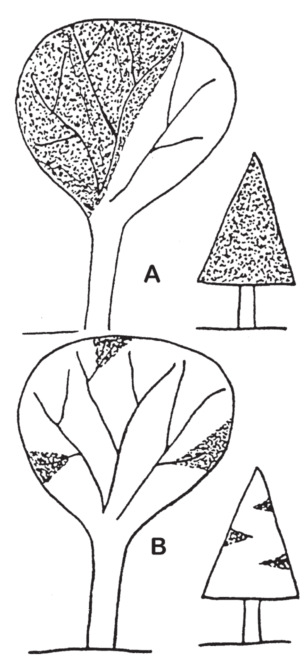
  Living organisms are specific, i.e. damage may be greatest on or limited to one species of plant.

  Living organisms multiply and grow with time, therefore they rarely afflict 100 percent of the host plants at one time. The damage is progressive with time. Likewise, the damage, generally, is initially limited to only one part of the plant and spreads from that initial point of attack with time.

  Living organisms usually leave "signs", i.e. excrement, cast skins, mycelium, eggs....

  Nonliving Factors: Damage patterns produced by nonliving factors such as frost or applications of toxic chemicals (Figure 5) are generally recognizable and widespread: Damage will usually appear on all leaves of a certain age (for example on all the leaves forming the plant canopy at the time a toxic spray was applied) or exposure (i.e. all leaves not shaded by overlapping leaves on the southwest side of a plant may be damaged by high temperatures resulting from intense sunlight). Damage will likely appear on more than one type or species of plant (look for similar damage patterns on weeds, neighboring plants, etc.) and over a relatively large area.

Figure 2.
Patterns on plant canopy:



A. **Entire or Major Portion of Top Dying:** If all or a major portion of a tree or shrub dies, suspect a problem with the roots. Look for Damaging Factor at the Junction of Normal and Abnormal Plant Tissue.

Gradual Decline of the entire plant or a major portion of it is caused by living factors such as root rots, vascular wilts and root-feeding insects or borers.

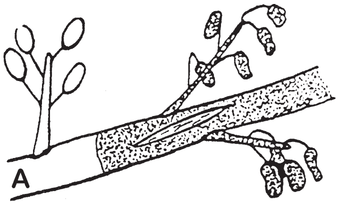
Sudden Decline is generally caused by a nonliving factor such as a toxic chemical in the soil or drastic climate changes such as freezing or drought.

B. **Single Branch Dying**: If only scattered damage occurs in the plant canopy, suspect that the primary problem is related to the foliage or aerial environment, - not the roots.

Gradual Death of Branch: If scattered branches start to decline and eventually die, suspect a living organism such as a canker pathogen, a shoot blight or borers.

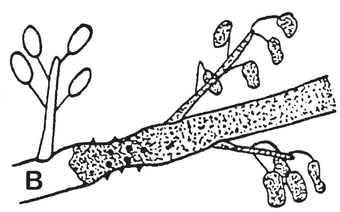
Sudden Death of Branch: If a branch dies suddenly, and especially if affected branches are concentrated on one side of the plant, suspect a nonliving factor such as weather (wind, snow, etc.), animal damage, or chemical drift.

Figure 3.
Shoot Dieback



A. **Shoot Dieback Caused by Nonliving Factors:** Sudden dying back of a shoot usually indicates a nonliving cause such as climatic or chemical damage, -not a living factor. Damage caused by nonliving factors usually results in a sharp line between affected and healthy bark and plant tissues. The exception would be bacterial blights which can kill shoots quickly.

If dieback is more gradual and there is also cracking of the bark and wood, suspect winter injury.



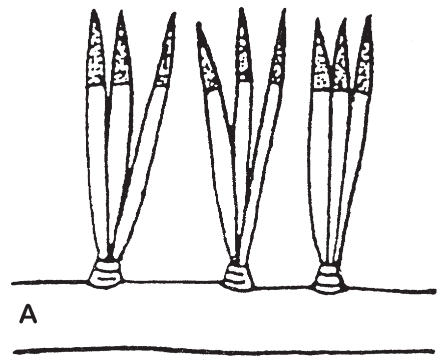
B. **Shoot Dieback (Blight) Caused by Living Factors**: Gradual decline of shoots and retention of dead leaves may indicate a living factor.

The margin between affected and healthy tissue is often irregular and sunken.

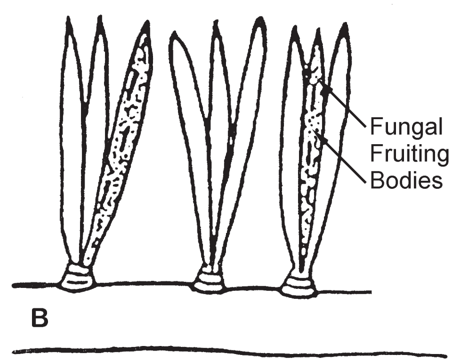
There may be small pinlike projections or bumps over surface of dead bark: These are spore producing structures of pathogenic fungi.

However, small, woody bumps radiating from all sides of twigs of Dwarf Alberta Spruce are pulvinus, -woody projections where needles were attached. This is a taxonomic identifying characteristic of spruce.

Figure 4.
Needle Damage

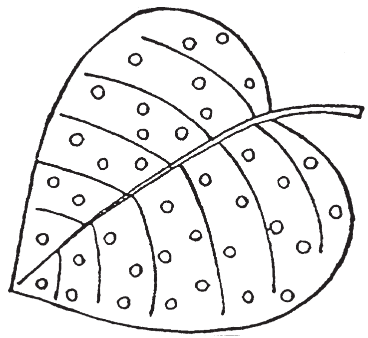


A. Death of the tips of conifer needles producing a uniform pattern usually indicates a nonliving factor such as toxic chemical or unfavorable climatic condition. Air pollutants frequently cause tip burn on conifers as do certain soil-applied herbicides or excess fertilizer. Drought and freezing may have a similar effect. In these cases all needles of a specific growth period are usually affected, and usually the same length on each needle is affected. The margin between the affected tissue, usually reddish brown, and healthy tissue is sharp and distinct.



B. Damage by living organisms such as fungi and insects to needles usually occurs in a random, scattered pattern and rarely kills all needles of a particular growth period. Needles are usually affected over varying lengths and often appear straw yellow or light tan in color. Black fruiting bodies of the causal fungus may be present on diseased needles.

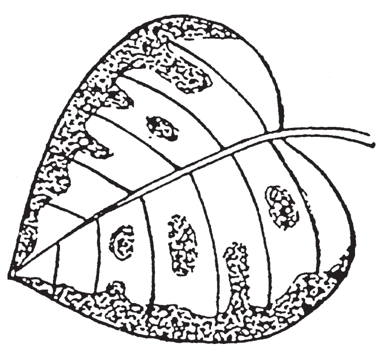
Figure 5.
Foliar Chemical Spray Injury Pattern on Leaf



Spots are usually uniformly and evenly distributed over the leaf surface and generally will be of uniform size. Color is usually uniform across the spot.

The margin between affected and healthy tissue is usually sharp. Injury pattern does not spread with time or move to previously undamaged plants or plant tissue.

Figure 6.
Leaf Damage Pattern by Nonliving Factors, i.e. toxic chemical taken up through roots or from polluted air filtered through the leaf or from moisture stress.



Injury from chemicals taken up by plants from soil through roots or from air through leaves usually results in scorching (necrosis) of leaf margins and interveinal areas. If severe, necrotic tissue may drop out giving a ragged appearance. Similar patterns are produced by moisture stress. If uptake of the toxic chemical is by a fully expanded leaf, toxicity is marginal and interveinal. If by a nonexpanded leaf, toxicity occurs in the veins.

III. Delineate Development

As already mentioned, another clue for distinguishing between living and nonliving factors causing plant damage is to observe the development of the patterns over time.

Living organisms generally multiply with time, producing an increasing spread of the damage over a plant or planting with time.

Nonliving factors generally damage the plant at a given point in time, for example death of leaf tissue caused by a phytotoxic chemical is immediate and does not spread with time (Figure 5). There are exceptions. If a nonliving damaging factor is maintained over time, the damage will also continue to intensify over time: For example, if a toxic soil or air chemical is not removed, damage to plants within the contaminated area will continue to develop (Figure 6), but damage will not spread to plants in uncontaminated areas: Nonliving Factors Are Not Progressive. This again re-emphasizes the necessity of piecing together multiple clues to identify the most probable factor causing plant damage.

IV. Determine Causes

Patterns of damage and distribution and patterns of development of damage over time have been valuable in making the gross distinction between damage caused by living factors and damage caused by non-living factors. Additional clues must be obtained to distinguish among factors within the living and nonliving categories.

Distinguishing Among Living Factors:

To further identify which subcategory of living factors caused the damage requires a close examination of the symptoms and signs.

Symptoms are the modified appearance of the affected plant, for example necrotic tissues, chlorosis, cankers, galls, leaf distortion.

Signs are the presence of the actual organism or evidence directly related to it. Visual observation of the insect on the leaf, presence of fungal mycelium, spores, insect egg masses, insect frass, mite webbing, etc. Signs can be used as clues in identifying the specific living organism that produced the plant damage.

A combination of clues from both symptoms and signs are required for preliminary distinction between damage caused by pathogens and insect-mite damage.

Symptoms and Signs of Pathogens

Differentiating between bacterial and fungal pathogens is not always clear cut, but certain symptoms are distinctive (Figures 7 and 8; Table 2).

Fungal Diseases (Figure 7).

Fungal leaf spots and stem rots are characterized by various symptoms: Dry texture, concentric rings, discoloration and fruiting structures. Fungal leaf spots and stem rots are usually dry or papery, especially in dry climates. The most distinguishing clue of a fungal disease is the presence of signs: Mycelium (common under conditions of high humidity and excessive moisture) and fruiting bodies of the fungus itself. The fruiting bodies range in size from microscopic to those easily detected with the naked eye. They are found within the leaf spot or stem rot area. Each type of fungus has its own characteristic structures which enable plant pathologists to identify them.

Foliar Pathogens: The leaf spots caused by fungi generally have distinct margins (Figure 7). They are usually circular with concentric rings resulting from growth of the fungus from the center point of initial infection outward. The condition of the leaf tissue and associated color ranges from dead (necrotic tan) in the center to recently dead (darker brown ring), to dying (darker ring with possible light yellow, chlorotic edge indicating the advancing edge of the fungal infection). The margins of fungal leaf spots (Figure 7) and stem rots (Figure 3) can be brightly discolored, such as purple (Fusarium stem rot) or yellow (*Helminthosporium* leaf spots), making these symptoms quite striking.

Root and Stem Pathogens: Root rots and vascular wilts result from fungal infections and destruction of root and stem tissues. The most common visual symptom is gradual wilting of the above ground shoots, and symptoms of nutrient deficiency.

Bacterial Diseases (Figure 8).

Bacteria do not actively penetrate healthy plant tissue like fungi. They enter through wounds or natural openings such as leaf stomata or twig lenticels. Once bacteria enter the plant, they reproduce rapidly, killing the plant cells.

Bacterial galls: In some cases, toxic materials are produced that cause plant tissues of roots, stems or leaves to grow abnormally as in crown gall.

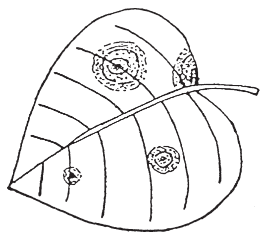
Bacterial leaf spot disease: The bacteria usually enter through leaf stomata or hydathodes. Symptoms include water-soaking, slimy texture, fishy or rotten odor, confined initially between leaf veins resulting in discrete angular spots. Many bacterial leaf spots, such as *Xanthomonas* leaf spot on Philodendron (also called red edge disease), expand until they reach a large leaf vein. This vein frequently acts as a barrier and inhibits the bacteria from spreading further. A chlorotic halo frequently surrounds a lesion. Lesions may enlarge through coalescence to develop blight lesions. Some lesions exude fluid containing bacteria. Water-soaking frequently occurs in bacterial leaf spot diseases, such as Erwinia blight of Dieffenbachia. Holding the leaf to light usually reveals the water-soaking. The ability of the bacteria (usually Erwinia species) to dissolve the material holding plant cells together results in a complete destruction of leaf or stem integrity. Some fungi also produce this symptom, but usually not as extensively as bacteria. In final stages, cracks form in the tissue and disintegration follows.

Vascular wilt: In some cases, the bacteria poison or plug the vascular water conducting tissues and cause yellowing, wilting, browning and dieback of leaves, stems and roots.

Table 2.
Symptoms & Signs of Fungal and Bacterial Leaf Spots

Abnormality	Fungal	Bacterial
Water-soaking	non common	common
Texture	dryish-papery	slimy-sticky
Odor	usually none	fishy, rotten
Pattern	circular with concentric rings	irregular-angular; initially does not cross veins
Disintegration	uncommon	common
Color changes	common: red, yellow, purple halos	uncommon
Pathogen structures	common - mycelia, spores	uncommon

Figure 7.
Fungal Leaf Spots

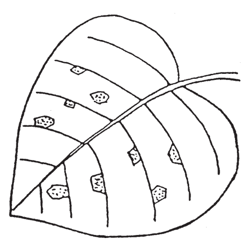


Spots usually vary in size, generally round, occasionally elongate.

Zones of different color or texture may develop giving the spot a bull's eye effect: The deadest tissue (tan) is in the center of the spot where the fungal spore germinated. Then as the fungus moves outward from that point of dead tissue to healthy tissue the foliage color changes from dead tan in the center to healthy green on the perimeter.

Spots are usually not limited by leaf veins.

Figure 8.
Bacterial Leaf Spots



Bacterial leaf spots are often angular because they are initially limited by the leaf veins.

Color of the bacterial spots is usually uniform. Bacteria are one-celled organisms that kill as they go. Tissue may first appear oily or water-soaked when fresh, but on drying becomes translucent and papery.

Viral Diseases (Figure 9).

Viruses are "submicroscopic" entities that infect individual host plant cells. Once inside a plant cell, they are able to infect other cells. Viruses are obligate parasites: They can only replicate themselves within a host's cell. Because the virus commandeers the host cell to manufacture viruses identical to itself, the plant cell is unable to function and grow normally. In the virus infected plant, production of chlorophyll may cease (chlorosis, necrosis); cells may either grow and divide rapidly or may grow very slowly and be unable to divide (distortion, stunting). The symptoms of most virus diseases can be put into four categories:

1) Lack of Chlorophyll formation in normally green organs.

    Foliage may be mottled green and yellow, mosaic, or ringed (yellow and other pigmented ring patterns), or be a rather uniform yellow (virus yellows).

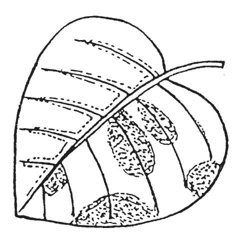
    Veins: Vein clearing is a common first symptom of some viral diseases. The veins have a somewhat translucent appearance. In vein banding there is a darker green, lighter green or yellow band of tissue along the veins.

2) Stunting or other growth inhibition: The reduction in photosynthesis, because of less chlorophyll, leads to shorter internodes, smaller leaves and blossoms and reduced yield.

3) Distortions of leaves and flowers, witches' brooms or rosettes result from nonuniform growth or uncontrolled growth of plant tissues.

4) Necrotic areas or lesions: Being obligate parasites, viruses require the survival of their host plant for their own procreation. Hence, viruses rarely cause death. Necrosis that does occur is usually confined to discrete areas of the plant; necrosis rarely occurs to such an extent that the entire plant is killed.

Figure 9.
Vein Clearing and Mosaic Leaf Patterns



Left side of leaf: vein clearing (chlorosis) with interveinal tissue remaining green usually indicates a virus disease or the uptake and xylem translocation of a herbicide such as diuron. This is in contrast to the leaf veins remaining green with surrounding chlorotic tissues usually associated with nutrient deficiencies such as iron deficiency.

Right side of leaf: Mosaic is a patchwork of green and yellow areas over the surface of the leaf. The leaf may also be puckered and distorted. These symptoms usually indicate a virus disease, especially if the yellow areas blend gradually into the green areas. If margins are distinct, mottling may indicate a nutritional problem or genetic variegation.

Viruses Typically Discolor, Deform or Stunt Plants rather than induce necrosis or cause death. Expressed symptoms (chlorosis, stunting, distortions) can be valuable clues for virus identification, but can be easily confused with symptoms induced by other problems such as nutritional disorders, spray injuries, or certain feeding damage induced by mites or insects. In addition, because of their extremely small size, the virus or signs of the virus are not visible to the unaided eye. The virus particles are detectable within the plant through the electron microscope.

Viruses are transmitted from plant to plant by insects, mites, fungi and nematodes, rubbing, abrasion or other mechanical means (including grafting or other forms of vegetative propagation). Viruses are occasionally transmitted in seed. Because of the nature of virus transmission, virus symptoms generally spread with time from one infected plant tissue to other plant tissues or from one infected plant to other plants in the community.

Nematodes:

Plant nematodes are microscopic roundworms that damage plant tissues as they feed on them. Many feed on or in root tissues. A few feed on foliage or other above-ground organs.

Shoot Nematodes (*Aphelenchoides* spp.)—Foliar nematodes feed inside leaves between the major veins causing chlorosis and necrosis. Injury is most often seen at the base of older foliage. When plants with a net-like pattern of veins become infested with foliar nematodes, the tissues collapse in wedge-shaped areas and then change color.

Root Nematodes— The most common above-ground symptoms caused by root-infesting nematodes result from damaged root systems: Moisture and nutrient stress symptoms and general stunting are common. The root lesion nematodes (*Pratylenchus* spp.) and burrowing nematodes (*Radopholus similis*) destroy the root cortex tissues as they feed. The root-knot nematodes (*Meliodogyne* spp.) inject growth-regulating substances into root tissues as they feed, stimulating the growth of large tender cells and causing overgrowth of root tissues to form visible, swollen “galls” or “knots”. Other root nematodes stunt growth, apparently by killing root meristems.

Symptoms and Signs of Insects, Mites and Other Animals

Insects

The location of the feeding damage on the plant caused by the insect’s feeding, and the type of damage (damage from chewing or from sucking mouth parts) are the most important clues in determining that the plant damage was insect-caused and aide in identifying the responsible insect.

An insect’s life cycle (complete or incomplete) is important when attempting to detect the insect or design a control program.

Feeding Habits

Chewing Damage or Rasping Damage

- Entire Leaf Blade Consumed by various caterpillars, canker worms, and webworms. Only tougher midvein remains.
- Distinct Portions of Leaf Missing. Distinct notches cut from leaf margin (black vine weevil adult), circular holes cut from margin of leaf (leaf cutter bees), small randomly scattered holes in leaf (beetles, chafers, weevils, grass-hoppers).
- Leaf Surfaces Damaged: “Skeletonization” of leaf surface. Slugs, beetle larvae, pearslug (pear sawfly larvae), elm leaf beetle, and thrips.
- Leaves “rolled”: Leaves that are tied together with silken threads or rolled into a tube often harbor leafrollers or leaftiers.
- Leaf Miners Feed Between the Upper and Lower Leaf Surfaces. If the leaf is held up to the light, one can see either the insect or frass (excrement) in the damaged area (discolored or swollen leaf tissue area), i.e. boxwood, holly, birch, elm leaf miners.
- Petiole and Leaf Stalk Borers burrow into the petiole near the blade or near the base of the leaf. Tissues are weakened and the leaf falls in early summer. Sectioning the petiole reveals insect-larva of a small moth or sawfly larva, i.e. maple petiole borer.
- Twig Girdlers and Pruners, i.e. vine weevil and twig girdling beetle.

- **Borers Feed** under the bark in the cambium tissue or in the solid wood or xylem tissue, i.e. Mountain pine beetle and smaller European elm bark beetle galleries. Damage is often recognized by a general decline of the plant or a specific branch. Close examination will often reveal the presence of holes in the bark, accumulation of frass or sawdust-like material or pitch, i.e. raspberry crown borer, Pine pitch moth.
- **Root Feeders**, larval stages of weevils, beetles and moths cause general decline of plant, chewed areas of roots, i.e. sod webworm, Japanese beetle and root weevil.

Sucking Damage

In addition to direct mechanical damage from feeding, some phloem-feeding insects cause damage by injecting toxic substances when feeding. This can cause symptoms which range from simple stippling of the leaves to extensive disruption of the entire plant. Insect species which secrete phytotoxic substances are called toxicogenic (toxin-producing) insects. The resulting plant damage is called "phytotoxemia" or "toxemia".

- **Spotting or Stippling** result from little diffusion of the toxin and localized destruction of the chlorophyll by the injected enzymes at the feeding site. Aphids, leafhoppers, and lygus bugs are commonly associated with this type of injury.
- **Leaf curling or Puckering** - More severe toxemias such as tissue malformations develop when toxic saliva causes the leaf to curl and pucker around the insect. Severe aphid infestations may cause this type of damage.
- **Systemic Toxemia** - In some cases the toxic effects from toxicogenic insect feeding spread throughout the plant resulting in reduced growth and chlorosis. Psyllid yellows of potatoes and tomatoes and scale and mealy bug infestations may cause systemic toxemia.
  Examples:
  - **General (uniform) "stipple" or Flecking or Chlorotic Pattern** on leaf i.e. adelgid damage on spruce needles and bronzing by lace bugs.
  - **Random Stipple Pattern** on leaf, i.e. leafhoppers, mites.
  - **Leaf and Stem "distortion"** associated with off-color foliage = aphids (distortion often confused with growth regulator injury) i.e. rose aphid, black cherry aphid, leaf curl plum aphid.
  - **Galls, Swellings** on leaf and stem tissue may be caused by an assortment of insects, i.e. aphids, wasps, midge, mossyrose gall wasp, popular petiole gall midge, azalea leaf gall.
  - **Damaged Twigs** - Split: damage resembling split by some sharp instrument is due to egg laying (oviposition) by sucking insects such as tree hoppers and cicadas. Splitting of the branch is often enough to kill the end of the branch, i.e. cicada.
  - **Root, Stem, Branch Feeders** - General Decline of Entire Plant or Section of a Plant as indicated by poor color, reduced growth or dieback. Scales, mealybugs, pine needle scale.

Insect Life Cycles

Knowledge of life cycles assists in identifying the damaging insect.

Incomplete Life Cycle:

Insects resemble the adult upon hatching, except they are smaller and without wings. As the insect grows, it sheds its skin or molts leaving cast skins as a diagnostic sign.

Lygus bugs, leafhoppers, and grasshoppers are examples of insects with incomplete life cycles.

Complete Life Cycle

Eggs, larva (caterpillar, wormlike or grub-like creature that may feed on various plant parts) pupa (relatively inactive, often enclosed in some form of cocoon), adult insect completely different in appearance. The larval stage with chewing and rasping feeding is most dangerous.

Examples of insects with complete life cycles are butterflies, moths, weevils, beetles and flies.

Other Animal Damage

Arachnids have sucking mouth parts and have 8 legs instead of six like the insects. **Spider Mites** have incomplete life cycles (mite resembling adult throughout life cycle). Damage is often a characteristic stipple pattern on leaf which then becomes pale color on underside (severe infestation causes leaf bronzing and death). Presence of "dirty" foliage - small fine webbing on the underside of the foliage mixed with eggs and frass. **Eriophyid Mites** - Distorted new growth, leaf margins roll, leaf veins swell and distort the leaf, (symptoms often confused with growth regulator damage).

Crustacea - Sowbugs and pill bugs feed on decaying vegetation. Not considered to be damaging to live plants.

Mollusca - Slugs and snails. Feeding injury to low growing foliage resembles Skeletonizing or actual destruction of soft tissue. Signs: presence of "silvering" and slime trails on foliage.

Miscellaneous Animals - Millipede and centipedes (arthropods) feed on decaying plant vegetation (many small legs, brownish or white in color, vary in size from ½-2"). Not considered injurious to live plants.

Small Mammals - Chewing of bark and cambium tissue on small trees and shrubs in most frequently caused by rodents (mice, rabbits, squirrels, and possibly beavers). Signs: Note teeth marks.

Large Mammals - Branches torn or clean cut by cattle, goats, deer and horses.

Birds - Yellow-bellied sap-sucker (even rows of holes in the tree trunk). Missing flower petals, puncture splitting of bark.

Distinguishing Among Nonliving Factors

If patterns of damage in the field planting and on the individual plant are uniform and repeated, this indicates that a nonliving factor is the probable cause of the damage. We will now examine additional information and clues to discover whether the nonliving damaging factor was a mechanical, physical, or chemical factor.

Look for Changes in the affected plant's environment caused by the three categories of Nonliving Factors: 1) Mechanical Factors (Damage/Breakage) - plant damage caused by site changes - "construction damage", transplanting damage, "Lawn mower blight", abrasion, bruising. 2) Physical Factors - environment or weather changes causing extremes of temperature, light, moisture-aeration. 3) Chemical factors - chemical pesticide applications, aerial and soil pollutants, nutritional disorders.

Mechanical Factors

Close visual examination and questioning will often determine if the stems or roots have been broken or girdled or if the leaves have been bruised, punctured or broken. For example, if a large *Fiscus elastica* is dropped while being transplanted and the stem is broken, rapid wilting of the portion of the plant above the break will occur. Examine the plant site for signs of recent excavation, construction, paving, etc.

Physical Factors

EnvironmentalFactors

Primary sources of diagnostic information are damage patterns and weather records to pinpoint the time and location of weather extremes. Records help indicate the factor that caused the plant damage.

TemperatureExtremes:

Heat: The highest leaf temperatures will occur in the early afternoon when the sun is located in the southwest quadrant of the sky. Therefore, lethal leaf temperatures produced by absorption of solar radiation will occur primarily on unshaded leaves on the outer surface of the plant canopy on the southwest side. Portions of leaves shaded by other leaves or leaves on the shaded northeast side may be undamaged. The most severe damage occurs on the leaves most exposed and furthest from the vascular (roots, stem, leaf vein) source of water, i.e. leaves on outer perimeter of plant, leaf tips and interveinal areas.

Cold: Damage will occur on the least hardy plants and will be most severe on the least hardy tissues of those specific plants. In fall acclimation, cold hardiness is first achieved by the terminal buds, and then with time the lower regions achieve hardiness; the branch crotches are often the last tissues to achieve cold hardiness. And, generally, the root systems will not survive as low a temperature as will the tops -root systems are damaged at higher temperatures than are the tops. On the other hand, after hardiness has been achieved, if warm temperatures induce deacclimation (i.e. in the early spring), the terminals (buds) are first to become less cold hardy.

Portion of plant damaged will indicate if low temperature damage occurred before plant achieved cold hardiness in the fall, or if it occurred after cold hardiness was lost in the spring: reverse patterns are produced.

On a given structure (i.e. leaf or bud) the damage will be death of exposed, nonhardy tissues in a recognizable (repeated) pattern. For example, frost damage to foliage, i.e. conifer needles, in the spring will uniformly kill all needles back toward the stem. Frost cracks are longitudinal separations of the bark and wood generally on the southwest sides of the trunk -most likely to occur because of daily, wide temperature fluctuations. Freezing death of dividing cells on the outer portions of leaf folds while inside the bud will cause a distorted or lace-like leaf blade because of nonuniform cell division and growth during leaf expansion. Cold damage to the root system is primarily a concern with container-grown plants where the root temperature fluctuates more and can be expected to reach lower temperatures than would occur with the same plant if field-grown. Cold damage to the root system can be detected by examining the roots: Damage generally occurs from the periphery of the root ball (near the container edge) and evidence includes blackened or spongy roots with lack of new growth or new root hairs. Above ground symptoms generally will not be evident until new shoot growth begins in the spring; at that time leaf expansion may be incomplete (small leaf size) because of the restricted uptake of water and nutrients by the damaged root system. With increased air temperatures, the water loss from the shoots and leaves may exceed the root uptake capacity and the plants may defoliate due to this water deficit.

Plants Vary in their Cold Tolerance: The cold tolerance (hardiness) of various plants in the landscape has been rated by the USDA (see Plant Hardiness Zone Map, USDA-ARS Misc. Pub. Np. 814). The "indicator plants" listed for the various cold hardiness zones on the map are useful in surveying a group of landscape plants, observing which ones show cold damage and then estimating how low the temperature dropped based on the damaged/undamaged indicator plants.

Light Extremes: Plants can acclimate to various conditions, but the primary requirement for acclimation is time. Plants respond adversely to rapid changes in the environment. Rapid change from low to high light intensity will result in destruction of the chlorophyll pigments in the leaf (yellowed and necrosis - sunburn). Rapid change from high to low light intensity will result in reduced growth and leaf drop; new leaves will be larger. "Sun leaves" are smaller, thicker and lighter green in color than are "shade leaves". Flowering will be reduced, delayed or absent under low light.

Oxygen and Moisture Extremes: Here we are primarily considering the root environment where oxygen and moisture are inversely related. Waterlogging (moisture saturation) of the root environment results in oxygen deficiency; without oxygen, root metabolism and growth come to a standstill. Consequently, uptake of water and nutrients is restricted with subsequent wilting and nutritional deficiency symptoms occurring on the above ground portions of the plant. Drought and water logging produce many of the same symptoms on the above ground portion of the plant: the first symptoms will be chlorosis and abscission of older leaves. Under severe, continuing moisture stress, wilting and necrosis will occur on the tips and interveinal regions of recently expanded leaves and new growth (Figure 6).

Chemical Factors

Field Patterns of Plant Injury Related to Chemical Applications

Look For Application, Drift, or Runoff Accumulation Patterns in the Field (Figure 10): the pattern of plant injury in a field or other group of plants and the date of injury appearance can be helpful in relating the damage to a specific chemical application.

Damage Diminishing Uniformly From One Side to the other (Figure 10.A, Spray Drift): A pattern in a field, yard or on a group of plants that starts on one side and diminishes gradually and uniformly away from that area is typical of wind-drifted droplets.

Damage in Individual Spots or Irregular Patterns (Figure 10.B): Low lying areas in a field where air masses settle would enhance the accumulation of fumes from volatile chemicals, would be frost pockets, and might enhance pathogens. These damage spots might also be related to differences in the soils texture, organic matter, pH or moisture. High pH spots might induce nutritional disorders such as iron deficiency, increase the toxicity of triazine herbicides, etc.

Damage in Linear Stripes at Regular Intervals, (Figure 10.C), indicates nonuniform application of a chemical. Regularly recurring stripes of damaged plants at intervals within the width of the application equipment (fertilizer applicator, pesticide spray boom, etc.) indicate an over-sized or worn nozzle, improper setting on one applicator opening, or an overlap in application. Another cause may be carry over of a residual chemical from bands applied the year before, this pattern would match row width and direction from the previous season.

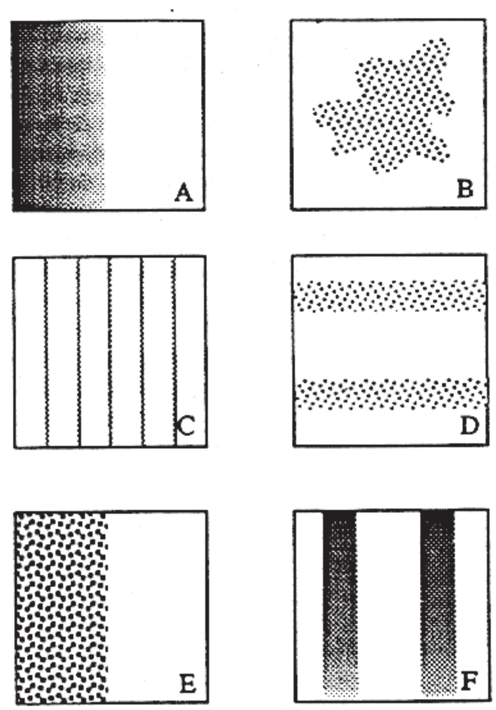
Damage At Ends of Field, (Figure 10.D), may be due to double application of a chemical either the year before or the year the injury is observed.

Damage on One Part of the Field Only with a Definite Break Between the Damaged Portion and the Remainder of the Field, (Figure 10.E), 1) Was the equipment reloaded or recalibrated at the break-point? If so, a mistake might have been made in the chemical selected or the rate of application, or the equipment might not have been adequately cleaned of a toxic chemical: the toxic residue was removed in the application of the first load of chemical. Check equipment-use records. 2) Check tillage methods, dates and soil conditions (moisture) -resulting differences in soil texture or depth of tillage may cause differences in dilution of carry over chemical residue, differences in volatilization and dilution of an applied chemical.

Damage Intensity Increasing Along a Broad Band, (Figure 10.F) indicates inadequate mixing or poor agitation of a wettable chemical powder in a spray tank resulting in increased concentration of the applied chemical toward the end of the tank load.

Figure 10.

Illustrations of patterns of plant damage related to chemical applications to field or bed plantings.



A) Drift of spray droplets.

B) Spots of injury from low temperature or accumulation of volatile chemicals or accumulation of chemical runoff in low areas of field; or, injury associated with soil variables.

C) Stripes indicating overlapping application pattern, or one or more faulty applicator openings.

D) Plant injury at end of field due to double application.

E) Definite break between injured and uninjured sections of the plantings: Application discontinued or change in applied chemical.

F) Increasing injury within an application band due to poor mixing or inadequate chemical agitation.

Chemical Injury Patterns on an Individual Plant

A general uniform pattern of damage occurring over several plant species and over a relatively large area indicates a nonliving factor such as a chemical phytotoxicity. Questions-answers, records, the plant symptoms and knowledge about the mobility within the plant of common chemicals (nutrients and pesticides) should help determine which chemical caused the damage.

Patterns of injury symptoms on an individual plant that develop because of deficiency, excess or toxicity of a chemical differ depending primarily upon whether the chemical causes damage directly on Contact, or is absorbed and distributed within the plant through Phloem-Translocation or through Xylem-Translocation.

Symptoms from Direct Contact of Chemicals with the Plant:

Shoot-Foliage Contact: Symptoms from shoot-contact or chemicals occur over the general plant canopy. If the toxic chemical is applied directly to the above ground parts of the plant (shoot-foliage contact chemical), the physical pattern of application may be detected, i.e. spray droplet size, etc. If the toxic chemical is spray-applied, the pattern of the spray droplets or areas where spray accumulated to runoff along the leaf edges will show the most severe damage. If it is a toxic gas (volatile chemical acting as an aerial pollutant), the areas between the leaf veins and along the leaf margins where the concentration of water within the leaf is lower will be the first to show damage. Injury from foliar applications of insecticides, fungicides and fertilizers is primarily of the direct-contact type and is typified by chlorotic-necrotic spotting, especially interveinally and along leaf edges and other areas where chemicals concentrate and are least diluted by inter-cellular moisture. Examples of shoot-foliage contact chemicals are foliar-applied fertilizer salts and herbicides such as paraquat, acifluorfen, dinoseb, and herbicidal oils. Fungicides and insecticides may also cause injury to some plants.

Root Contact: Toxic contact chemicals in the root zone, including excess fertilizer, result in poor root development or death. Symptoms from root-contact chemicals are localized where the chemical contacts the root but also result in general symptoms in the shoot. The shoots may show water and nutrient stress symptoms, i.e. reduced growth, wilting, nutrient deficiency symptoms.

The injury symptoms on the shoot and foliage from root damage by direct contact with toxic chemicals or excessive salts resembles a drying injury -the roots are unable to obtain water. This will result in a general stunting of the plant. In severe cases, wilting can occur even though the soil is wet. Lower Leaves generally wilt first and this is followed by drying of the leaf margins. Many factors injuring or inhibiting root growth may produce similar shoot symptoms: Nematodes, soil compaction, cold weather, salinity, nutritional disorders and certain herbicides (dinitroanilines, DCPA, and diphenamid) cause root inhibition.

Symptoms of Deficient or Toxic Trans-located Chemicals

The effects of mobile chemicals absorbed by the plant are dependent upon whether the chemical is transported in the phloem or in the xylem. If transported solely in the xylem system, the chemical will move upward in the plant in the xylem-transpiration stream.

Toxic symptoms from xylem-translocated chemicals occur primarily in the older foliage.

Deficiency symptoms of xylem-transported (phloem-immobile) nutrient ions will occur first in the new growth.

If the chemical is translocated in the phloem, it may move multidirectional from the point of absorption, i.e. it may move from the shoot to the root or the reverse.

Toxic symptoms from phloem-translocated chemicals occur primarily in the new growth and meristematic regions of the plant.

Deficiency symptoms of phloem-retranslocated nutrient ions occur first in the older foliage.

Xylem Translocated Chemicals Move Primarily Upward in the Plant to the Foliage

Chemicals are translocated upward in the xylem (apoplastic movement) of the plant from the point of absorption. Symptoms occur in tissues formed after the toxicity or deficiency occurs.

- Toxic Chemicals -xylem translocated. When toxic chemicals are translocated to fully expanded, older leaves, the toxicity symptoms generally appear on the leaf margins and interveinal areas. When toxic chemicals are translocated to immature, young leaves, the toxicity symptoms generally appear associated with the veins, especially the midrib.

Photosynthetic-Inhibiting Chemicals - Injury from translocated toxic chemicals is primarily to the foliage. Plant injury generally progresses from the lower, older foliage to the top. Individual leaves show greatest injury (chlorosis) along their tips and margins or along the veins. Examples of xylem-translocated herbicides include the photosynthetic inhibitors such as triazine, urea and uracil herbicides.

Shoot-Inhibiting Chemicals - Examples of toxic chemicals absorbed by the roots and translocated in the xylem to the shoots are the "shoot inhibiting herbicides". The shoot inhibitors cause malformed and twisted tops with major injury at the tips and edges of the leaves; looping of the leaves may occur since the base of the leaf may continue to grow while the leaf tips remain twisted together. Thiocarbamate herbicides cause these symptoms on both grasses and broad leaves. Alachlor and metolachlor herbicides cause similar injury symptoms on grasses.

- **Deficiency Nutrient Ions, xylem-translocated (phloem immobile)**

  Several nutrient ions are translocated upwards in the xylem and are immobile after incorporation into plant tissues. They cannot be withdrawn and retranslocated in the phloem to the new growth when deficiencies develop in the root zone. Deficiency symptoms of Phloem-Immobile nutrient ions develop on the new growth. Boron and calcium are quite phloem-immobile which means that if the external supply becomes deficient, the symptoms of boron and calcium deficiency will appear in the new growth. And, with severe deficiencies, the terminal bud dies. Iron, manganese, zinc, copper and molybdenum are also relatively phloem-immobile and are not readily withdrawn from the older leaves for translocation through the phloem to younger leaves and organs. Deficiency symptoms are most pronounced on the new growth.

Phloem Translocated Chemicals Move Multidirectionally from Point of Application or Source of the Chemical to the Meristematic Regions.

- **Toxic Chemicals - Phloem translocated**

  Injury from Phloem-translocated toxic chemicals - primarily to new leaves and roots because of translocation of the chemicals to the meristems. Whether taken up by the roots or shoots, these compounds are moved through the living plant cells and phloem (symplastic movement) to both the root and shoot tips. The young tissue (shoots or roots) will be discolored or deformed and injury may persist for several sets of new leaves. Examples of phloem-translocated toxic chemicals, whether absorbed by the roots or shoots, include the herbicides 2,4-D, dicamba, picloram, glyphosate, amitrole, dalapon, sethoxydim and fluazifopbutyl. These compounds move to the meristems and typically injure the youngest tissues of the plant.

- **Deficient Nutrient Ions - Phloem mobile**

  If Phloem Mobile Nutrient Ions become deficient in the root zone, these ions may be withdrawn from the older plant tissues and retranslocated in the phloem to the new growth. In such situations, deficiency symptoms will first occur on the older leaves. Elements that may be withdrawn from older leaves and retranslocated in the phloem to younger leaves and storage organs include nitrogen, phosphorus, potassium, magnesium, chlorine and, in some plant species, sulfur. Sulfur: In plant species where sulfur can be withdrawn from the older leaves and translocated to the newer growth, deficiency symptoms may initially occur on the older leaves or over the plant in general. In plants where sulfur is not readily re-translocated, the older leaves may remain green and the sulfur deficiency symptoms occur only on the new growth.

Key to Symptoms of Chemical Disorders on Individual Plants

I. Symptoms Appearing First or Most Severely on New Growth

(root and shoot tips, new leaves, flowers, fruits, buds)

A. Terminal Bud Usually Dies. Symptoms on new growth.

1. Basal part of young leaves and internal tissues of organs may become necrotic. One of the earliest symptoms is failure of the root tips to elongate normally. Terminal shoot meristems also die giving rise to a witch's broom. Young leaves become very thick, leathery, and chlorotic; in some species young leaves may be crinkled due to necrotic spots on leaf edges during development. Young leaves of terminal buds become light green then necrotic and the stem finally dies back from the terminal bud. Rust colored cracks and corking occur on young stems, petioles, and flower stalks. "Heart rot" of beets, "stem crack" of celery ... **Boron Deficiency**

2. Necrosis occurs at tip and margin of leaves causing a definite hook at leaf tip. Calcium is essential for the growth of shoot and root tips (meristems). Growing point dies. Margins of young leaves are scalloped and abnormally green and, due to inhibition of cell wall formation, the leaf tips may be "gelatinous" and stuck together inhibiting leaf unfolding. Stem structure is weak and peduncle collapse or shoot topple occurs near terminal bud. Ammonium or Magnesium Excess may induce a calcium deficiency in plants ... **Calcium Deficiency**

   Differentiating between calcium and boron deficiency symptoms: When calcium is deficient, there is a characteristic hooking of the youngest leaf tips. However, when boron is deficient, the breakdown occurs at the bases of the youngest leaves. Death of the terminal growing points is the final result in both cases.

3. Tissue Breakdown -necrosis and firing of the tip and margins of the leaf. The ammonium cation itself may become phytotoxic and result in breakdown of the plant tissue (proteolysis= breakdown of plant proteins) initially producing a wet, dark-green, "steamed" appearance at the leaf tips and margins. This destroyed tissue eventually desiccates and becomes a light tan color. Excess ammonium may also induce calcium deficiency (abnormally dark green foliage, scalloped leaf margins, weak stem structure, death of terminal bud or growing point of the plant, premature shedding of the blossoms and buds) ... **Ammonium Excess**

B. Terminal Bud Remaining Alive. Symptoms on new growth.

1. Interveinal chlorosis on young leaves.

   a. Interveinal chlorosis on young leaves with larger veins only remaining green. Necrotic spots usually absent; with extreme deficiencies, however, young leaves are almost white and may have necrotic margins and tips; necrotic areas may extend inward. Potassium, Zinc or Copper Excess can inhibit uptake of iron. High pH may also induce iron deficiency ... **Iron Deficiency**

   Iron deficiency symptoms are similar to those of magnesium deficiency, but iron deficiencies occur in young leaves first: Iron accumulated in older leaves is relatively immobile in the phloem.

   b. Interveinal chlorosis with smallest veins remaining green producing a checkered or finely netted effect. Grey or tan necrotic spots usually develop in the chlorotic areas; the dead spots of tissue may drop out of the leaf giving a ragged appearance. Poor bloom -both in size and color. Potassium excess can inhibit uptake of manganese... **Manganese Deficiency**

   c. Stunted new growth with interveinal chlorosis: Young leaves are very small ("little leaf"), sometimes missing leaf blades altogether, and internodes are short giving a rosette appearance ... **Zinc Deficiency**

2. Interveinal chlorosis is not the main symptom on new growth

   a. Wilting and loss of turgor of young, terminal leaves and stem tips is common. Symptoms are highly dependent upon plant species. In some species younger leaves may show interveinal chlorosis while tips and lobes of older leaves remain green followed by veinal chlorosis and rapid, extensive necrosis of leaf blade ... **Copper Deficiency**

There are no known reports of $H_2PO_4^{-1}$ toxicity; however, plants may take up the phosphate anion in luxury amounts. Phosphorus excess is associated with impeded uptake and possible deficiency of copper and sometimes of zinc ... ***Phosphorus Excess***

b. Leaves light green, veins lighter in color than adjoining interveinal areas. Leaves over entire plant may become yellowish green, roots and stems are small in diameter and are hard and woody. Young leaves may appear to be uniformly yellow. Some necrotic spots ... **Sulfur Deficiency**

In plant species where the sulfur is not withdrawn from older leaves and retranslocated to the new growth, leaves matured prior to onset of sulfur deficiency remain green: This retention of green color in older foliage distinguishes sulfur deficiency in these species from nitrogen deficiency where the nitrogen is translocated from the older foliage into the new leaves. With nitrogen starvation, old leaves as well as new leaves turn yellow.

c. Shoot inhibition causing malformed and twisted tops with major injury at the tips and edges of the leaves ... **Xylem-Translocated "Shoot-Inhibiting Chemicals"**

Examples of toxic xylem-transported chemicals include the thiocarbamate herbicides (symptoms on grasses and broad leaf plants) and alachlor and metolachlor (symptoms on grasses)

d. Young tissues discolored or deformed and injury may persist for several sets of new leaves ... **Toxic Phloem-Translocated Chemicals**

Examples of Toxic Phloem-Transported Chemicals include the herbicides 2,4-D; dicamba; picloram; glyphosate; amitrole; dalapo; sethoxydim and fluazifopbutyl.

II. Symptoms Do Not Appear First on Youngest Leaves:

Effect general on whole plant or localized on older, lower leaves.

A. Chlorosis General, no interveinal Chlorosis. Effects usually general on whole plant.

1. Visible symptoms include yellowing and dying of older leaves. Foliage light green, growth stunted, stems slender, yellow ... **Nitrogen Deficiency**

   Plants receiving enough nitrogen to attain limited growth exhibit deficiency symptoms consisting of a general chlorosis, especially in older leaves. In severe cases, these leaves become completely yellow and then light tan as they die. They frequently fall off the plant in the yellow or tan stage.

2. Older leaves wilt. Entire leaf is affected by chlorosis, but edges and leaf tissues near main veins often retain more color (chlorophyll) ... **Zinc Excess**

B. Vein-Clearing, Chlorosis-Necrosis at Leaf Tips and Margins, older-younger foliage ... Xylem-Transported Photosynthetic-Inhibitors

When toxic chemicals are xylem-translocated to older, fully-expanded leaves, the toxicity symptoms generally occur on the margins and interveinal areas of the leaf. When translocated to young, expanding leaves, toxicity symptoms are generally associated with the veins, especially the midrib.

Examples of Xylem-Translocated, Photosynthetic Inhibitors include the triazine, urea and uracil herbicides.

C. Interveinal Chlorosis. Interveinal Chlorosis first appears on oldest leaves.

1. Older leaves chlorotic, usually necrotic in late stages. Chlorosis along leaf margins extending between veins produces a "Christmas tree" pattern. Veins normal green. Leaf margins may curl downward or upward with a puckering effect. Necrosis may suddenly occur between the veins. Potassium or calcium excess can inhibit uptake of magnesium... **Magnesium Deficiency**

When the external magnesium supply is deficient, interveinal chlorosis of the older leaves is the first symptom because as the magnesium in the chlorophyll is remobilized, the mesophyll cells next to the vascular bundles retain chlorophyll for longer periods than do the parenchyma cells between them. Leaves lose green color at tips and between veins followed by chlorosis or development of brilliant colors, starting with lower leaves and proceeding upwards. The chlorosis/brilliant colors (unmasking of other leaf pigments due to the lack of chlorophyll) may start at the leaf margins or tips and progress inward interveinally producing a

"Christmas" tree pattern. Leaves are abnormally thin, plants are brittle and branches have a tendency to curve upward. Twigs are weak, subject to fungus infection, leaves usually drop prematurely; plant may die the following spring.

2. Smaller veins in older leaves may turn brown. Small necrotic spots in older leaves spread from the margins inwards, and finally the entire leaf blade desiccates. At severe, advanced stages, young leaves also display this spotting... **Manganese Excess**

3. Chlorotic areas (pale yellow) on whole plant; leaf edges curl upward ... **Molybdenum Deficiency**

   General symptoms are similar to those of nitrogen deficiency: Interveinal chlorosis occurs first on the older or midstem leaves, then progresses to the youngest. Sometimes, as in the "whiptail" disease, plants grown on ammonium nitrogen may not become chlorotic, but develop severely twisted young leaves, which eventually die. Other characteristic molybdenum deficiency symptoms include marginal scorching and rolling or cupping of leaves. With molybdenum deficiency, nitrogen deficiency symptoms may develop in the presence of adequate levels of nitrate nitrogen in the root environment and high levels of nitrate nitrogen in the plant. Nitrate nitrogen must be reduced in the plant before it can be utilized. Molybdenum is required for this reduction, and if molybdenum is deficient, nitrate may accumulate to a high level in the plant, and at the same time the plant may exhibit nitrogen deficiency symptoms. Molybdenum differs from other trace nutrients in that many plants can develop in its absence provided that ammonium nitrogen is present. Molybdenum appears to be essential for the nitrate-reducing enzyme to function.

4. Foliar marginal necrosis is the most common symptom of fluoride toxicity along with chlorosis along and between the veins in fluorine-sensitive plants. With many plants, the marginal necrosis is preceded by the appearance of gray or light-green, water-soaked lesions which later turn tan or reddish-brown. Injury generally occurs at the tips of the leaves first, then moves inward and downward until a large part of the leaf is affected ... **Fluoride Excess**

D. Leaf Chlorosis is Not the Dominant Symptom. Symptoms appear on older leaves at base of plant.

1. Plant dark Green

a. At first, all leaves are dark green and growth is stunted. Purple pigment often develops in older leaves, particularly on the underside of the leaf along the veins. Leaves drop early... **Phosphorus Deficiency**

   Phosphorus deficiency is not readily identified by visual symptoms alone. Visual symptoms of phosphorus deficiency are not always definite, but many phosphorus deficient plants exhibit off-color green foliage with purple venation, especially on the underside of leaves, and plants are stunted and remain stunted even when fertilizers supplying potassium and nitrogen are applied. Older leaves assume a purple-bronze color. Small growth, especially root development; spindly growth with tips of older leaves often dead. Phosphorus is phloem retranslocated from older leaves to new growth. Often enhanced by cold soil temperatures.

   Aluminum appears to affect root growth in particular: root tips blacken, no longer lengthen, and become thickened. Excess aluminum accumulation in roots reduces their capacity for translocating phosphorus. Amelioration involves suppression of aluminum activity, for example by liming soil to bring the pH above 5.5. The toxic amount of aluminum in a soil will depend upon other soil properties such as pH and phosphorus content and upon the plant grown. Media amendments such as perlite may release toxic quantities of aluminum if the media pH is extremely acid ... **Aluminum Excess**

b. Leaves are thick and brittle and deep green. In acute toxicity, older leaves wilt and scorch from the margins inward ... **Nitrate Excess**

2. Necrotic spots develop on older leaves

a. Margins of older leaves become chlorotic and then burn, or small chlorotic spots progressing to necrosis appear scattered on old leaf blades, calcium excess impedes uptake of potassium cations... **Potassium Deficiency**

   Potassium deficiency symptoms first appear on the recently matured leaves of the plant (not on the young, immature leaves at the growing point). In some plants, the first sign of potassium deficiency is a white specking or freckling of the leaf blades.

With time, the symptoms become more pronounced on the older leaves, and they become mottled or yellowish between the veins and scorched at the margins. These progress upward until the entire leaf blade is scorched. If sodium cations are present and taken up in place of K^{+1}, leaf flecking (necrotic spots scattered on leaf surface) and reduced growth occur. Seed or fruit is shriveled. Potassium is phloem retranslocated from old leaves to new growth.

b. Tips and edges of leaves exhibit necrotic spots coalescing into a marginal scorch. Symptoms appear from the plant's base upwards with older leaves being affected first. In advanced, severe toxicity, necrotic spots with a pale brown center also appear in the inner parts of the leaf blade... **Boron Excess**

c. Mottling and necrotic spots primarily on margins and interveinally may be due to excessive amounts of fertilizers or pesticides applied as foliar sprays ... **Direct-Contact of Toxic Chemical with Shoot & Foliage**

   Examples of shoot direct-contact toxic chemicals producing this type of symptom include the shoot-foliage applied herbicides paraquat, acifluofen, dinoseb and the herbicidal oils.

3. Reduced growth and wilting of older leaves with development of chlorotic and necrotic spots. Roots become stunted in length and thickened, or club-shaped, near the tips: the shoots remain normal but may show nutrient and moisture stress. Under severe conditions, root tips may be killed causing general stunting of the plant or wilting followed by marginal drying of the lower leaves first... **Direct-Contact Injury by Toxic Chemicals** or other factors in the root zone, i.e. low temperatures; nematodes; root weevils.

   Examples of Root Direct-contact Toxic Chemicals include excess salts or presence of toxic chemicals such as the herbicides DPA, dinitroanilines, diphenamid.

   Leaves often become bronze colored ... **Chloride Deficiency**

4. Marginal scorching that may progress to general leaf scorching. Generally no spotting ... **Excess Salt or Sodium Excess**

5. Intense yellow or purple color in leaves. Molybdenum excess or toxicity in field-grown plants is rarely observed. Plants appear to tolerate relatively high tissue concentrations of molybdenum. Isolated reports of symptoms from excess molybdenum include development of intense yellow color in tomato leaves and intense purple color in cauliflower leaves... **Molybdenum Excess**

References, Laboratory Analyses

If you have identified the plant and have narrowed the probable cause down through the various categories (i.e. distinguished between living and nonliving - then if living distinguished between pathogens and animal factors - then if pathogen, distinguished between fungal and bacterial organisms), you will probably need assistance in identifying the specific responsible organism or nonliving factor. But, by now you know what specialist to contact (plant pathologist, entomologist, physiologist ...) and what specific reference book would provide further assistance in narrowing down the search for the specific factor causing the observed plant damage. Laboratory analyses and examination may be required to further narrow the range of probably causes.

V. Synthesis of Information to Determine Probable Causes of plant Damage

The detective work to find the "signs" (residues of the living, damaging organism or nonliving factor, records, etc.) is time consuming and methodical. But, without this process of elimination and synthesis, the probability of making a correct diagnosis is low.

Table 3. Summary:

Systematic Approach to Diagnosing Plant Damage

I. Define the problem (determine that a "real" problem exists):

A. Plant Identification and Characteristics. Establish what the "normal" plant would look like at this time of year. Describe the "abnormality": Symptoms & Signs.

B. Examine the Entire Plant and its Community. Determine the primary problem and part of the plant where the initial damage occurred.

II. Look for Patterns: On more than one plant? On more than one plant species?

A. Non-uniform Damage pattern (scattered damage on one or only a few plant species) is indicative of Living Factors (pathogens, insects, etc.)

B. Uniform Damage Pattern over a large area (i.e. damage patterns on several plant species) and uniform pattern on the individual plant parts indicate Nonliving Factors (mechanical, physical, or chemical factors).

III. Delineate Time-development of Damage Pattern

A. Progressive spread of the damage on a plant, onto other plants, or over an area with time indicates damage caused by Living Organisms.

B. Damage occurs, does not spread to other plants or parts of the affected plant. Clear line of demarcation between damaged and undamaged tissues. These clues usually indicate Nonliving Damaging Factors.

IV. Determine Causes of the Plant Damage. Ask questions and gather information.

A. Distinguish Among Living Factors
   1. Pathogens - Symptoms and signs.
   2. Insects, mites and other Animals - Symptoms and signs.

B. Distinguish Among Nonliving Factors
   1. Mechanical Factors
   2. Physical Factors
      a. Temperature extremes
      b. Light extremes
      c. Oxygen and moisture extremes
      d. Weather records
   3. Chemical Factors
      a. Analyze damage patterns in fields and other plantings
      b. Injury patterns on individual plants
      c. Pesticide-pollutant phytotoxicities - damage patterns
      d. Nutritional disorders - key to nutritional disorders
      e. Spray records

C. References (check reports of damaging factors on identified plant); may need Laboratory Analyses to narrow range of probably causes.

V. Synthesis of Information to Determine Probable Causes

Literature Useful for Diagnosing Plant Diseases & Disorders

I. Miscellaneous

The Ortho Home Gardener's Problem Solver. 1993. Smith, C. A. ed. Ortho Books, San Ramon, CA. 400 pp.

The Organic Gardener's Handbook of Natural Insect and Disease Control. 1992. B. A. Ellis and F. M. Bradley, eds. Rodale Press, Emmaus, PA. 534 pp.

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Compendium of Strawberry Diseases. 1984. Maas, J. L. APS Press, St. Paul, MN. 138 pp.

V. Turfgrass

Compendium of Turfgrass Diseases, 2nd ed. 1983. Smiley, R. W. , Dernoeden, P. H and Clarke, B. APS Press, St. Paul, MN. 204 pp.

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VIII. Disease Indices

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Titles in **BOLD** lettering are highly recommended.
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