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A SYSTEMATIC APPROACH TO DIAGNOSING PLANT DAMAGE

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A SYSTEMATIC APPROACH TO DIAGNOSING PLANT DAMAGE

Introduction

To determine what factors damaged a plant requires an inquisitive, investigative approach combined with careful observation and the ability to put all the pieces together to reconstruct the event(s) that produced the plant damage. Accurate diagnosis must be made before corrective action can be taken; even if no corrective measures are available, there is satisfaction in simply knowing what the problem is and what its future development might be.

Probability of correct diagnosis based on only one or two clues or symptoms is low. Similarities of symptoms produced on the same plant by completely different factors frequently make the use of symptoms alone inadequate.

In diagnosing plant damage a series of deductive steps can be followed to gather information and clues from the big, general situation down to the specific, individual plant or plant part. Through this systematic, diagnostic process of deduction and elimination, the most probable cause of the plant damage can be determined. Steps to follow in gathering diagnostic information are presented in Table 1. Each step will then be expanded and guidelines presented as we proceed through the diagnostic process. We will first identify the problem, then attempt to distinguish between living and nonliving damaging factors based on the observed damage patterns, development of the patterns with time, and other diagnostic signs.

Factors causing plant damage can be grouped into two major categories:

- 1. **Living factors**: living organisms such as pathogens (fungi, bacteria, viruses, nematodes) and pests (insects, mites, mollusks, rodents...). With living factors, **"Something is missing, and something is gained."**
- 2. **Nonliving factors**: *mechanical* factors (i.e. breakage, abrasions, etc); physical, environmental factors (extremes of temperature, light, moisture, oxygen, lightning); and, chemical factors (chemical phytotoxicities, nutritional disorders, etc).

Table 1. Flow Model for 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 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 and plant parts indicates 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 indicate nonliving damaging factors.

IV. DETERMINE CAUSES OF THE PLANT DAMAGE. Ask questions and gather information.

A. Distinguish among living factors

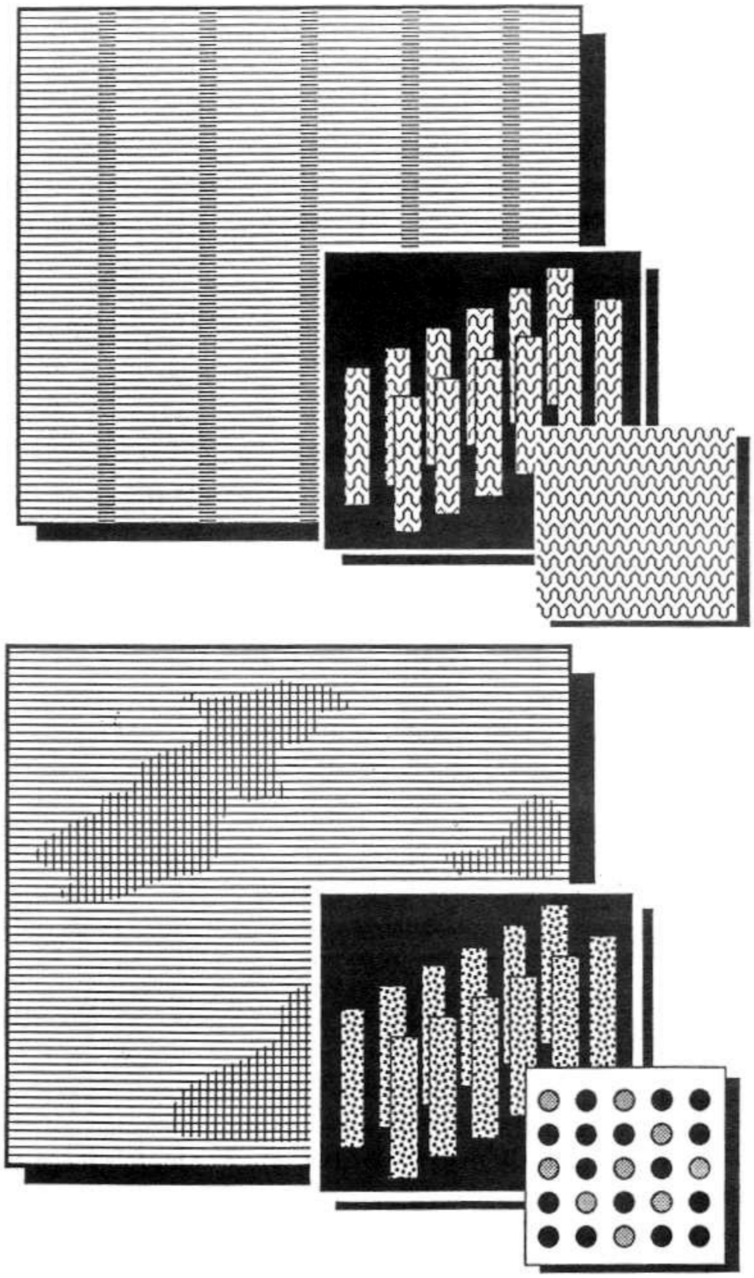
1. Symptoms and signs of PATHOGENS.
2. Symptoms and signs of INSECTS, MITES, and OTHER ANIMALS.

B. Distinguish among nonliving factors

1. MECHANICAL FACTORS
2. PHYSICAL FACTORS
   a. Temperature extremes
   b. Light extremes
   c. Oxygen and moisture extremes
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.

C. References (check reports of damaging factors on identified plant); may need LABORATORY ANALYSES to narrow range of probable causes.

V. SYNTHESIS OF INFORMATION TO DETERMINE PROBABLE CAUSES.



PATTERNS –

Signs to direct the diagnosis of

PLANT DAMAGE

If we suspect that it is a **living damaging** factor, we will look for signs and symptoms to distinguish between pathogens and insects. If the accumulated evidence suggests that it is a pathogen, we will seek evidence to distinguish among fungal, bacterial, viral pathogens and nematodes. If the evidence indicates the damaging factor is an insect or other animal, we will seek further evidence to distinguish between sucking and chewing types.

If evidence indicates that the damage is being caused by a **nonliving factor,** we will seek further evidence as to whether the initial damage is occurring in the root or aerial environment. We will then attempt to determine if the damage results from MECHANICAL FACTORS, from extremes in PHYSICAL FACTORS (i.e. environmental factors such as extremes of temperature, light, moisture, oxygen), or from CHEMICAL FACTORS (i.e. phytotoxic chemicals or nutritional disorders). Once we have identified the plant and limited the range of probable causes of the damage, we can obtain further information to confirm our diagnosis from reference books, specialists such as plant pathologists, entomologists, horticulturists, and/or laboratory analyses.

I. DEFINE THE PROBLEM

Plant identification and characteristics -growth and appearance of the "identified "plant -Normal? -Abnormal?

Determine that *real* problem exists. It is essential that the plant be identified (genus, species and cultivar or variety) so that the normal appearance of that plant can be established either by personal knowledge or by utilizing plant reference books. Many horticultural plants, or structures on those plants such as fruits-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 *typical* diseased plant with a healthy or normal plant, since normal plant parts or seasonal changes are sometimes mistakenly assumed to be evidence of disease. Examples are the brown, spore-producing bodies on the lower surface of leaves of ferns. These are the 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 rootknot 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 characteristic 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 residues; records of weather extremes or chemical applications; damage patterns). **PATTERNS OF DAMAGE ARE EXCELLENT SIGNS and are definitive 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. Look for the factor causing the damage at the periphery of the plant 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 by 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.

II. LOOK FOR PATTERNS

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

Non-uniform 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 or removed, 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 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.

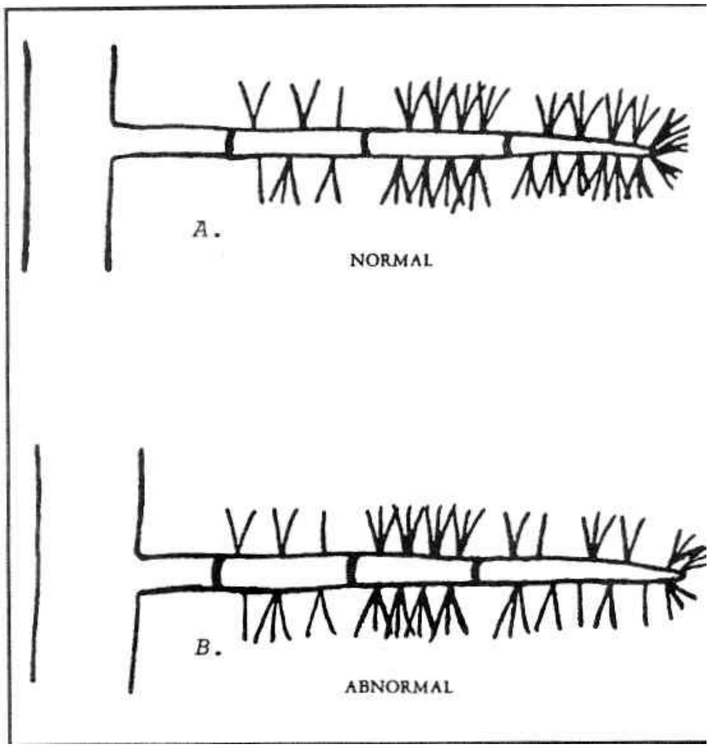


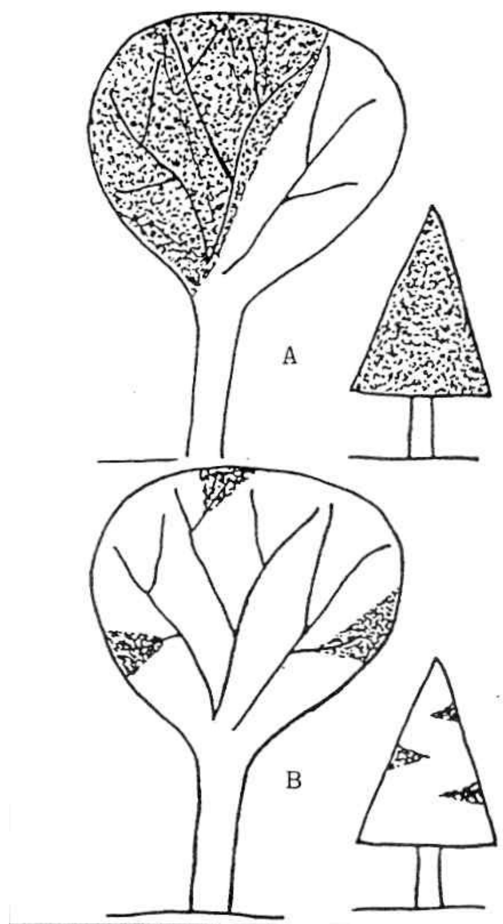
FIGURE 1. ***Normal*** **vs** ***abnormal*** **needle drop or leaf drop from evergreens.**

Nondeciduous plants normally retain their leaves 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.

FIGURE 2. **Patterns on plant canopy:**



A. Entire or major portion of top dying. If all or major portion of tree or shrub dies, suspect a problem with the roots. LOOK FOR DAMAGING FACTOR AT JUNCTION OF NORMAL AND ABNORMAL PLANT TISSUE.

Gradual decline of entire plant or a major portion of it is caused by living factors such as Armillaria root rot, Verticillium wilt and rootweevil.

Sudden decline is generally caused by a nonliving factor such as a toxic chemical in soil or drastic climatic 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 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.

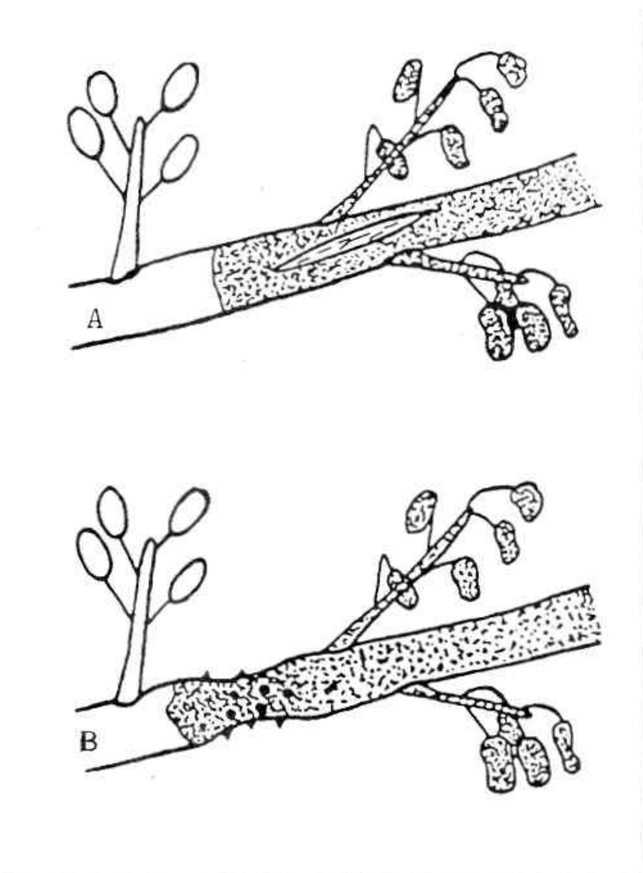


Figure 3. Shoot dieback

A. Shoot dieback caused by nonliving factors: Sudden dying back of a shoot usually indicates 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.

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

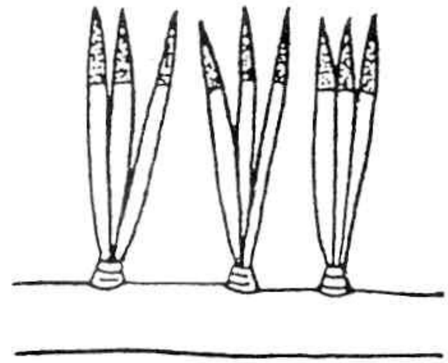
B. Shoot dieback (blight) caused by living factors: Gradual decline of shoots and retention of dead leaves may indicate a living factor.

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

Death of the tips of conifer needles producing a uniform pattern usually indicates a nonliving factor such as a 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. Margin between the affected tissue, usually reddish brown, and healthy tissue is sharp and distinct.



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 causal fungus maybe present on diseased needles.

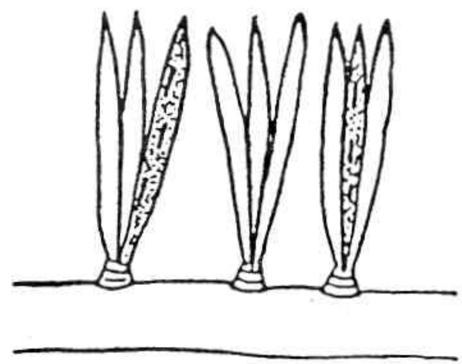


FIGURE 5. Foliar chemical spray injury pattern on leaf.

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.

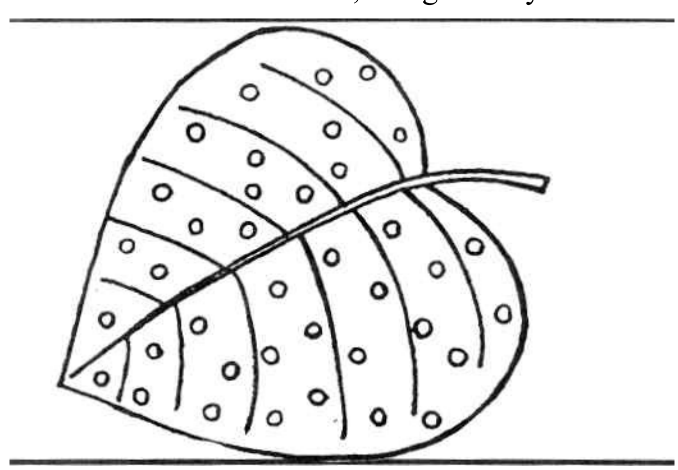


FIGURE 6. Leaf damage pattern by nonliving factors, i.e. toxic chemical taken up through roots or from polluted air filtered through the leaf, or from moisture stress.

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.

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 pattern.

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

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 with 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 distribution and time patterns in development of damage have been valuable in making the gross distinction between damage caused by living factors and damage caused by nonliving 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 factor caused the damage, requires a close examination of the symptoms and signs.

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

Signs are 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 pathogen 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. This is especially true in dry climates. The leaf spots caused by fungi generally have distinct **margins (Fig. 7).** Many times they are circular with concentric rings resulting from growth of the mycelium from the center point of initial infection outward (much like crocheting a doily): 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 **(Fig. 7)** and stem rots **(Fig. 3)** can be brightly discolored, such as purple (Fusarium stem rot) or yellow (Helminthosporium leaf spot), making these symptoms quite striking.

TABLE 2. SYMTPOMS & SIGNS OF FUNGAL AND BACTERIAL LEAF SPOTS

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

The most distinguishing clue of a fungal disease is the presence of signs: Mycelium 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.

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. Symptoms include water-soaking, slimy texture, fishy or rotten odor, confined initially between leaf veins resulting in discrete spots that have straight sides and appear angular. 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 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 not usually as extensively as Erwinia. In general, bacterial infections show this characteristic more than fungal infections. In final stages, cracks form in the tissue and disintegration follows.

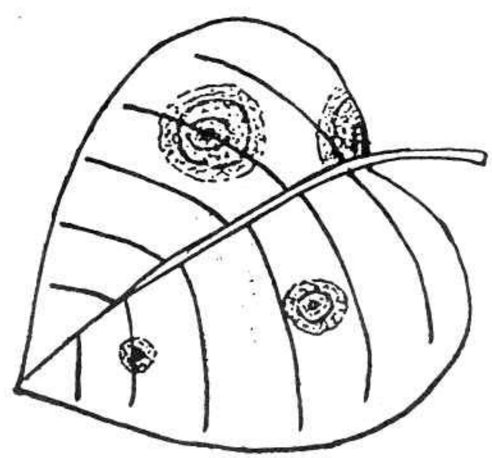


FIGURE 7: fungal leaf spots. Spots usually vary in size, generally round, occasionally elongate on stems.
Zones of different color or texture may develop giving the spot a bull's eye effect: The deadest tissue (tan) is in the center of the spot where the fungal spore germinated. Then as the fungal mycelium front moves outward from that point of dead tissue to healthy, not yet infected tissue, on the perimeter, the foliage color changes from dead tan in the center to healthy green on the perimeter.
Spots are not limited by leaf veins since mycelium grows on leaf surface.

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

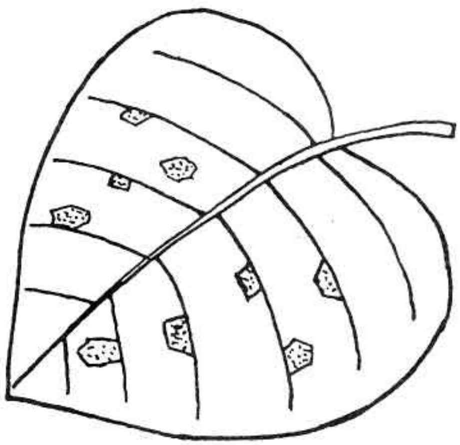


FIGURE 8. Bacterial leaf spots.

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 tan

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 or 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 or transparent 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 within a tissue or uncontrolled growth.

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.

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 cell 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.

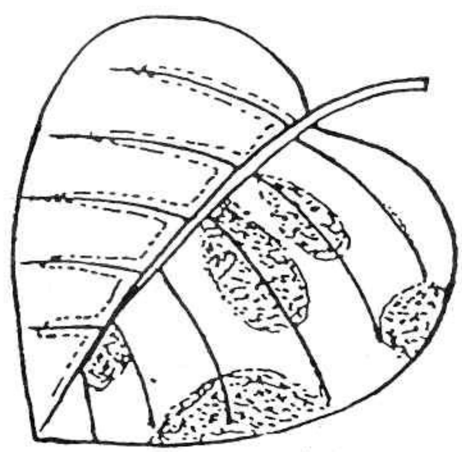


FIGURE 9. Vein clearing and mosaic leaf patterns.

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

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

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 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 *(Meloidogyne* spp.) inject growth-regulating substances into root tissues as they feed, stimulating growth of large tender cells to provide themselves a permanent feeding site, and causing overgrowth of root tissues around them 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 is insect-caused and 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, i.e. omnivorous leaftier.

- **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 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 leaf falls in early summer. Sectioning petiole reveals insect-larva of 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, Sequoia 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, 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".** - (Chapman, R.K. 1985. Insects that poison plants. American Vegetable Grower 33-10:3138, October 1985).

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 plant 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.

- **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, poplar 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, 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. Adult stage is most damaging.

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

Complete Life Cycle:

Eggs, larva (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. Larval stage is most damaging.

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**, incomplete life cycle (mite resembles 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 - Sow bugs 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 - Millipeds and centipedes (arthropods) feed on decaying plant vegetation (many small legs, brownish or white in color, vary in size from 1/2 - 2"). NOT CONSIDERED INJURIOUS TO LIVE PLANTS.

SMALL MAMMALS - Chewing of bark and cambium tissue on small trees and shrubs is most frequently 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.

IV. DETERMINE CAUSE OF DAMAGE (continued)

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 determine whether the nonliving damaging factor was a mechanical, physical, or chemical factor.

Look for CHANGES in the three categories of NONLIVING FACTORS of the affected plant's environment: 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, moistureaeration. 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 Ficus 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 (Environmental Factors)
Primary sources of diagnostic information are damage patterns and weather records to pinpoint time and location of weather extremes. Records are "signs" of the factor that caused the plant damage.

Temperature Extremes:

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 solar radiation absorption 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 maybe undamaged. Most severe damage occurs on 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. A recognizable pattern related to leaf tissue that would have the highest potential temperature and be most readily desiccated will occur uniformly over all plants in the area.

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 of a given age from the tip of the needle back toward the stem a given distance on each needle. 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 outer portions of leaf folds inside the bud will cause 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 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; 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. No.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. Differences in cold tolerance of root systems (especially roots of plants grown in exposed containers) are presented by Green (Ornamentals Northwest Newsletter 12-5:3-15,1988).

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 (yellowing 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 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 runoffaccumulation patterns in the field (figure 10): The pattern of plant injury in a field or other group of plants and 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-drift of droplets.

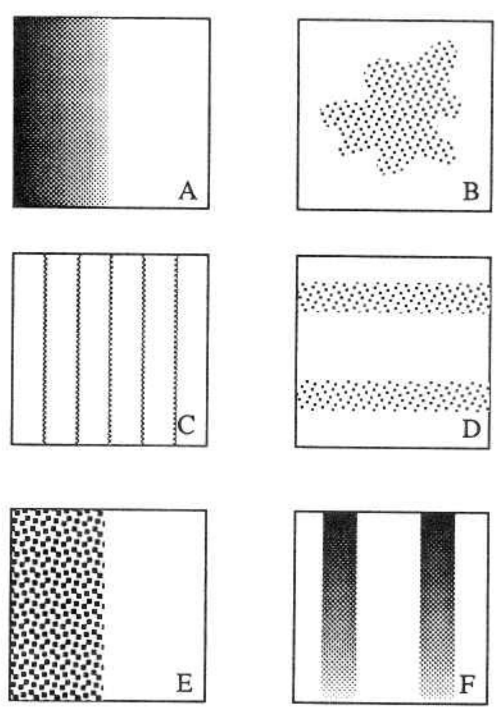


Figure 10. **Illustrations of patterns of plant damage related to chemical applications to field or bed plantings.** A) Drift of spray droplets. B) Spots of injury from low temperature or accumulation of volatile chemicals or accumulation of chemical runoff in low areas of the field; or, injury associated 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 planting: Application discontinued or change in applied chemical. F) Increasing injury within an application band due to poor mixing or inadequate chemical agitation.

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 carryover of a residual chemical from bands applied the year before -this pattern would match the 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 chemical applicator reloaded or recalibrated at the break-point? If so, mistake might have been made in chemical selected or in rate of application, or the applicator might not have been adequately cleaned of a toxic chemical: the toxic residue was removed in 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 carryover chemical residue, differences in volatilization and dilution of an applied chemical, etc.

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 tankload.

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 the 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 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 spray droplets or areas where spray accumulated to runoff along the leaf edges will show 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 chemical concentrates and is least diluted by inter-cellular moisture. Examples of SHOOT FOLIAGE CONTACT CHEMICALS are foliar-applied fertilizer salts and the herbicides paraquat, acifluorfen, dinoseb, and herbicidal oils.

Root contact: toxic contact chemicals in the root zone, including excess fertilizer, result in poor root development. Symptoms from root-contact chemicals are localized where the chemical contacts the root, but produce 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. Roots are injured and root tips may be killed. 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 a marginal drying of the leaves. 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 Translocated 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 (phloemimmobile) 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

Chemical is 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**

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 the 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 broadleaves. Alachlor and metolachlor herbicides cause similar injury symptoms on grasses.

- **DEFICIENT NUTRIENT IONS, xylem-translocated** (phloem immobile)

Several nutrient ions after upward translocation in the xylem and incorporation in plant tissue are immobile: They cannot be withdrawn when deficiencies develop in the root zone and retranslocated in the phloem to the new growth. 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 first on 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 is primarily to new leaves and roots because of translocation of chemical 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 tissue 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 because of necrotic spots on leaf edge during development. Young leaves of terminal buds become light green then necrotic and stem finally dies back at 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 may occur. Roots are stunted. Premature shedding of fruit and buds is common. Downward curl of leaf tips (hooking) 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 in 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; however, with extreme deficiencies, young leaves are almost white and may have necrotic margins and tips; necrotic spots 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 chlorotic areas; the dead spots of tissue may drop out of the leaf giving a ragged appearance. Poor bloom -both 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 the older leaves and retranslocated to the new growth, leaves matured prior to onset of sulfur deficiency remain green: This retention of green color of 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-TRANSPOR TED CHEMICALS include the thiocarbamate herbicides (symptoms on grasses and broadleaves) 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, dalapon, sethoxydim and fiuazifopbutyl.*

II. SYMPTOMS *DO* NOTAPPEAR FIRST OR MOST SEVERELY 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

• 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 puckering effect. Necrosis may suddenly occur between 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 of 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, usually leaves drop prematurely; plant may die the following spring.

2. SMALLER VEINS IN OLDER LEAVES MAY TURN BROWN. Small necrotic spots in older leaves spread margins inwards, and finally desiccate the entire leaf blade. 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 occurring first on the older or midstein I leaves, then progressing to the youngest. Sometimes, as in the "whiptail" disease, PLANTS GROWN ONAMMONIUM NITROGEN MAYNOT 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. Molybdenum deficiencies are commonly found in Northeastern Washington.

4. Foliar MARGINAL NECROSIS is the most common symptom of fluoride toxicity along with Chlorosis along and between the veins occurs 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.

Aluminum appears to affect root growth in particular: **ROOT TIPS BLACKEN, NO LONGER LENGTHEN, BUT BECOME THICKENED**. Excess aluminum accumulation in roots reduces their capacity for translocating phosphorus. Amelioration involves suppression of aluminum activity, for example by liming to bring the medium's pH above 5.5, and not by addition of phosphorus. 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 inward 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. Symptom 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 MARGIN AND INTERVEINALLY may leaves due to excessive amounts of fertilizers or pesticides applied either as foliar sprays... DIRECT CONTACT OF TOXIC CHEMICAL WITH SHOOT & FOLIAGE

- EXAMPLES OF SHOOT DIRECT-CONTACT TOXIC CHEMICALS INCLUDE the shoot foliage applied herbicides paraquat, acifluofen, dinoseb and the herbicidal oils produce this type of symptom.

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, 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 chemical such as the herbicides DCPA, dinitroanilines, diphenamid. LEAVES OFTEN EVENTUALLY 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 fieldgrown 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 probable causes.

V.SYNTHESIS OF INFORMATION TO DETERMINE PROBABLE CAUSES OF THE 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, probability of making a correct diagnosis is low.

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 initial damage occurred.

II. LOOK FOR PATTERNS: on more than one plant? On more than one plant species?

A. Nonuniform damage pattern (scattered damage on one or only a few plant species) is indicative of LIVING FACTORS (pathogens, insects, ate).

B. **Uniform damage pattern** over a large area (i.e. damage patterns on several plant species) and uniform pattern on the individual plant and plant parts indicates 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 indicate NON-LIVING DAMAGING FACTORS.

IV. DETERMINE CAUSES OF THE PLANT DAMAGE. Ask questions and gather information.

A. DISTINGUISH AMONG LIVING FACTORS
- 1. PATHOGENS - Symptoms and sign,,.
- 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
- 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.

C. REFERENCES (check reports of damaging factors on identified plant); may need LABORATORY ANALYSES to narrow range of probable causes.

V. SYNTHESIS OF INFORMATION TO DETERMINE PROBABLE CAUSES.

ANNOTATED BIBLIOGRAPHY

General diagnostic references: keys to plant identification and diagnosis of plant problems

DISEASES OF TREES AND SHRUBS. 1987. Wayne A. Sinclair, Howard H. Lyon and Warren T Johnson. This Comprehensive, up-to-date reference book has 576 pages, 247 color plates, 18 black-and-white illustrations in a 9 x 12 inch page-size format is priced at $49.95. An easily used, authoritative reference that is a reliable diagnostic aid that focuses on what can be seen with the unaided eye or with a hand lens. Includes diagnostic information on plant damage caused by both pathogen and nonliving factors such as environmental extremes, mechanical-physical damage, and chemical disorders. The book is available from: Cornell University Press, 124 Roberts Place, P.O. Box 250, Ithaca, NY 14851-0250.

WOODY ORNAMENTALS: PLANTS AND PROBLEMS. 1980. R. E. Partyka, J. W Rimelspach, B. G. Joyner, S. A. Carver. Produced, published and copy-righted by ChemLawn Corp, 450 West Wilson Bridge Road, Columbus, OH. Printed and distributed by Hammer Graphics, Inc., P O. Box 640, Piqua, Ohio, 45356. This hardback, 429-page book contains over 400 color pictures and over 400 black-and-white illustrations to assist the amateur as well as the professional in identifying plants, diagnosing plant disorders, and problem solving. It is well-organized (and, cross referenced), fairly complete in detail, and written in easy to understand language.

This book can be purchased for $36.50 from: agAccess, PO. Box 2008, Davis, CA 95617.

The major sections are: Plant identification characteristics (taxonomic key, plant illustrations and color photos); functions of plant parts; disease problems; insect problems and other animal pests; physiological disorders; chemical injury; trouble-shooting plant problems; ornamental plant problems key (diagnostic key with plants listed alphabetically by common names -latin genus and species and common name are cross referenced both ways in the Botanical Name Index and the Common Name Index in the back of the book) with color photo illustrations of common symptoms; and, avoiding and solving plant problems. There are two appendices: Appendix A, Plant Recommendations Based on Susceptibility to Problems; Appendix B, Plant Recommendations for Specific Problems.

The "Plant Problem Key" and accurate photographs of plant problems are very valuable diagnostic tools.

This is one of the most useful books for assistance in diagnosing plant problems.

MANUAL OF WOODY LANDSCAPE PLANTS. (Their identification, ornamental characteristics, culture, propagation, and uses). Third edition, revised in 1983. Michael A. Dirr. Published by Stipes Publishing Company, 10-12 Chester Street, Champaign, IL 61820. This book does exactly what the title indicates plus it indicates the more prevalent problems that might occur with each plant species and cultivar such as insect and pathogen problems, cultural requirements (i.e. pH, soil moisture, etc). It supplies valuable information on identifying characteristics of a range of cultivars of each species so the diagnostician can determine if the plant's appearance is normal for that cultivar. The information on propagation and culture is also useful in diagnosing plant problems.

HILLIER'S MANUAL OF TREES & SHRUBS, 5th edition, 1981. Harold G. Hillier. Van Nostrand Reinhold Company Inc, 135 West 50th St, New York, NY 10020. This reference provides descriptions and information on identifying characteristics of the significant cultivars of over 700 genera of landscape plants.

DIAGNOSIS OF PLANT DISEASES. Extension Bulletin 0751 (WSU Bulletin Department, Coop. Extn. Svc., Cooper Publications Bldg., Washington State University, Pullman, WA 99164-592, cost 25 cents/copy). Revised 1982. Otis C. Maloy.

DISEASES AND PESTS OF ORNAMENTAL PLANTS, 5th Edition. 1978. P P. Pirone. John Wiley and Sons, Inc.

FOLIAGE PLANT PRODUCTION. 1981. Jasper N. Joiner, Editor. Published by Prentice-Hall, Inc. Englewood Cliffs, NJ 07632. This book includes chapters on prevention and diagnosis of foliage plant problems: pathogens, insects and mites, nutritional and environmental disorders.

FOLIAGE PLANT PROBLEMS, A PICTORIAL ATLAS OF. 1983. Richard W Henley, editor. Available for $5.00/copy from: Florida Foliage Association, P.O. Box Y, Apopka, FL 32703.

40-page manual with approximately 160 full-color illustrative photographs has seven major sections: physiological disorders, plant diseases, insect and mite injury, nematode injury, other pest damage, pesticide phytotoxicity, and other problems. In addition to the printed diagnostic information and symptom description of the major problems occurring on foliage plants, each is accompanied by a color photo further depicting the problem.

HOW TO IDENTIFY RHODODENDRON AND AZALEA PROBLEMS, Extension Bulletin 1229 by A. L. Antonelli, R. S. Byther, R. R. Maleike, S. J. Collman, and A. D. Davison of Washington State University. Available for $3.50 from: Bulletin Office, Cooper Publications Building, WSU, Pullman, WA 99164-5912 (Make check payable to: Cooperative Extension Publications).

This 28-page publication is organized by symptoms: 1) Missing portions of leaves. 2) Spotting, discoloration, or dead areas on leaves. 3) Curling, distortion, or misshapen plant parts. 4) Powdery, granular or other unusual material on leaves or stems. And, 5) Dieback, total decline or poor performance. Forty, high-quality, color photographs clearly illustrate the described plant symptoms and, in many cases, the causes --insects, pathogens, cultural or environmental factors

CHRISTMAS TREE PEST MANUAL. October 1983. Janine M. Benyus, Writer/Editor. United State Department of Agriculture, Forest Service, North Central Forest Experiment Station. 108 pages. $14.00/copy from U.S. Government Printing Office, Washington, D.C. 20402.

Color photographs and descriptions of 70 Christmas tree problems will help growers, nursery workers, extension personnel, foresters, and students identify the cause of tree injury. Describes ways to prevent or reduce damage from insects, pathogens, birds, mammals, and environmental factors. Covers North Central and Northeastern U.S. and Southeastern Canada.

This manual is well-written, beautifully designed, and well-indexed and cross-referenced for easy use. The color photographs are of high quality and clearly illustrate the diagnostic signs and symptoms.

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REFERENCES REGARDING SPECIFIC FACTORS CAUSING PLANT PROBLEMS:
Living factors - problem diagnosis
Insect & mite injury diagnosis

PNW INSECT CONTROL HANDBOOK. Revised and published annually. For sale by: OSU Book Stores, Inc., P O Box 489, Corvallis, OR 97330.

INSECT AND MITE CONTROL IN ORNAMENTALS, EB 0826, revised September 1984. By: Arthur Antonelli (Extension Entomologist, WWREC, Puyallup, WA) and Sharon Collman (WSU-King County Extension Agent, Seattle, WA). Available for $1.00 from: Bulletin Office Cooper Publications Building, WSU, Pullman, WA 99164-5912 (Make check payable to: Cooperative Extension Publications).

This 45-page spray guide is for both the homeowner and the professional pesticide applicator. Homeowners may use only those materials listed in the publication that are not marked with asterisks. Information is presented in table form: plant groups, i.e. beginning with `alder' and ending with `yew', with associated information for each are arranged alphabetically for quick reference. For each plant, the common pests with descriptions, insecticide and amount of insecticide per gallon of water to use for control, and remarks are listed. The `remarks' column is especially useful and contains information such as time of year pest is prevalent, whether repeat applications might be necessary, possible phytotoxicity, etc. There is also a section titled "General Pests - Ornamentals" that presents identifying characteristics of the pest, insecticide to use for control, and remarks. This is a convenient, easily used publication.

WESTERN FOREST INSECTS. USDA Forest Service Miscellaneous Publication No. 1339. November 1977. R. L. Furniss and V M. Carolin. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock Number 001-000-03618-1). This is one of the most-used entomology reference books on my shelf. The extensive host index and general index to the information make it very easy and quick to locate needed information on a plant or pest. The clarity and completeness of the information on each pest including life cycles and photo-illustrations are invaluable in identifying and diagnosing pest problems on woody plants.

INSECTS THAT FEED ON TREES AND SHRUBS. 1976. W T. Johnson and H. H. Lyon. Cornell University Press, 124 Roberts Place, P.O. Box 250, Ithaca, NY 148510250, $49.50 + $1.50 postage and handling. This 9 X 12, 464 page book has 212 color plates and 32 illustrative figures. This reference provides information about more than 650 species of insects that can injure woody ornamental palnts in North America. It will enable the reader to diagnose plant disorders caused by pests and to identify the insect or mite responsible.

PATHOGEN DIAGNOSIS

PACIFIC NORTHWEST PLANT DISEASE HANDBOOK. Revised and published annually. For sale by: OSU Book Stores, Inc., P 0 Box 489, Corvallis, OR 97330.

DISEASE CONTROL IN THE LANDSCAPE, Bulletin 614. 1985. Charles C. Powell, Jr. The Ohio State University Cooperative Extension Service Publications Office, 2120 Fyffe Rd., Columbus, OH 43210. $3.50/copy + 54 cents postage. This 25-page bulletin provides information on the common pathogenic diseases of landscape flowers, shrubs, vines, groundcovers and trees in Ohio.

DIAGNOSING ORNAMENTAL PLANT DISEASES, An Illustrated Handbook. 1988. Randolph Keim and Wesley A. Humphrey. Publication 21446, University of California Cooperative Extension Service. Available from ANR Publications, Univ. CA., 6701 San Pablo Ave., Oakland, CA 94608-1239, $13/copy. This 36-page handbook contains 129 color photographs. It is divided into two sections: Section I describes general disease symptoms and steps in diagnosis; Section II is an alphabetical list of hosts for many diseases commonly found on ornamentals. This handbook is a guide, not a final answer.

THE DIAGNOSIS OF PLANT DISEASES, A Field and Laboratory Manual Emphasizing the Most Practical Methods for Rapid Identification. For Extension and Teaching Personnel and Those in Inspection Services and Commercial Agriculture. 1969. Rubert B. Streets, Sr. Cooperative Extension Service and Agricultural Experiment Station, The University of Arizona, Tucson, AZ. 12 Chapters. Available from AgAcess, P.O. Box 2008, Davis, CA 95617, telephone (916) 756-7177, $14.95/copy + $1.50 shipping charge.

This is a practical guide to equipment, methods, and information for field and laboratory "clinic" diagnosis of plant pathogens. This book is in the OSU Kerr Library, SB 731, S84. This book is an excellent guide and reference for anyone who is planning or operating a plant pathogen diagnostic laboratory whether at an individual nursery site or as a consulting service.

DISEASES OF MAPLES IN EASTERN NORTH AMERICA (A-23) by George W Hudler, Asst. Prof. of Plant Pathology, Cornell University. Available from: Cornell Distribution Center, 7 Research Park, Ithaca, NY 14850 ($1.75, includes postage and handling).
This 16-page, full-color illustrated bulletin describes more than 20 disorders of maples, including the species they affect, the causal pathogen and what its usual effect is on the host tree.

COMPENDIUM OF ELM DISEASES. 1981. R. Jay Stipes and Richard J. Campana, editors. Available for $11.00/copy from: American Phytopathological Society Books, 3340 Pilot Knob Road, St. Paul, Minnesota 55121.

120 pages, 199 color illustrations, 103 black and white illustrations. This compendium compiles world-wide information on major and minor diseases of elm trees with emphasis on Dutch Elm Disease. It is written as a ready reference for nurserymen, landscapers, foresters, arborists. It is arranged for fast reference. Included is a guide to the identification of diseases and a glossary

that translates scientific terms into understandable language. Disease control information is also included.

COMPENDIUM OF RHODODENDRON AND AZALEA DISEASES. 1986. Edited by Duane L. Coyier and Martha K. Roan. Available from: American Phytopathological Society Books, 3340 Pilot Knob Road, St. Paul, Minnesota 55121.

65 pages, 80 color photos, 12 black and white illustrations. This compendium compiles information on living organisms damaging plants (pathogens and insects) and nonliving damaging factors (extremes of moisture, temperature; nutritional disorders; chemical phytotoxicities, i.e. aerial pollutants, pesticides). The major sections are: Part 1. Diseases caused by infectious agents (pathogens); Part 2. Insect pests; Part 3. Noninfectious agents; Part 4. Beneficial organisms; and, "Aid to Diagnosis".

COMPENDIUM OF ROSE DISEASES. 1983. R. Kenneth Horst. Available for $17.00 from: American Phytopathological Society Books, 3340 Pilot Knob road, St. Paul, Minnesota 55121.

50 pages, 14 pages of color plants, 18 black and white photographs and illustrations. This is a practical reference.

DISEASES OF TURFGRASSES, Extension Bulletin 713, Washington State University Cooperative Extension Service. Charles J. Gould, Roy L. Goss and Ralph Byther. Available for $1.25 from: Bulletin Office, Cooper Publications Building, WSU, Pullman, WA 99164-5912 (Make check payable to: Cooperative Extension Publications).

This 40-page bulletin with color photographs of the various diseases contains diagnostic/control information within 6 major sections: Introduction, key to selected turfgrass diseases, major diseases, minor diseases, physiological and other miscellaneous problems, disease resistance and quality rating tables, chart showing prevalence of major turfgrass diseases during the year.

DISEASES OF TULIPS, Extension Bulletin 711, Washington State University. Charles J. Gould and Ralph S. Byther. Available for $1.50 from: Bulletin Office, Cooper Publications Building, WSU, Pullman, WA 99164-5912 (Make check payable to: Cooperative Extension Publications). 23-page bulletin with color photographs illustrating effects of many of the described diseases. Major sections are: major diseases, virus diseases, miscellaneous diseases, physiological diseases, and key to major tulip diseases. Under each disease, information on symptoms, factors affecting, importance and host range, causal agent, control, and references for further reading.

DISEASES OF NARCISSUS, Extension Bulletin 709, Washington State University. Charles J. Gould and Ralph S. Byther. Available for $2.00 from: Bulletin Office, Cooper Publications Building, WSU, Pullman, WA 99164-5912 (Make check payable to: Cooperative Extension Publications). 27-page bulletin with color photographs illustrating the symptoms of many of the described diseases. Under each disease information on symptoms, factors affecting, importance, control and causal agent, and references are provided.

WESTCOTT'S PLANT DISEASE HANDBOOK. 1979. Fourth Edition, Revised by R. Kenneth Horst. 803 pp. This easily used reference has two main sections: Information on individual pathogens and control methods; and, an extensive listing by host plant of the pathogens, including viruses, that have been reported on that plant. The book is well indexed for fast location of information.

NONLIVING FACTORS -PROBLEM DIAGNOSIS

Herbicide injury diagnosis

APPLIED WEED SCIENCE. 1985. Merrill A. Ross and Carole A. Lembi (Purdue University). 340 pp, hard cover. Burgess Publishing Company, Minneapolis, Minnesota. The authors' writing style is not stilted or heavy with technical jargon. The book is very well-written: information is accurate, concise, clearly phrased and presented in a logical sequence. It is an interesting book that holds the reader's attention. The information is "applied" in the sense that the reader can readily relate the information to actual plant production and weed control situations. Chapter 1.4 on "Troubleshooting" is a useful guide to diagnosing the cause(s) of herbicide failure or injury problems. Interpretation of observed "patterns", information to collect when making an on-site investigation, identifying injury symptoms on individual plants, and interpreting findings are explained. The book is well indexed and cross-referenced so the reader can quickly find specific information. The "Glossary" provides quick definition of terms. Available for $29.95/copy from AgAecess + $1.50 shipping charge, PO. Box 2008, Davis, CA 95617, telephone (916) 756-7177.

PNW WEED CONTROL HANDBOOK. Revised and published annually. For sale by: OSU Book Stores, Inc., P O Box 489, Corvallis, OR 97330.

DIAGNOSIS AND PREVENTION OF HERBICIDE INJURY. Extension Bulletin E-809. Michigan State University.

DIAGNOSIS OF HERBICIDE DAMAGE TO CROPS. 1981. D. J. Eagle and D. J. Calerly. 70 pages. Chemical Publishing Company, 155 West 19th Street, Dept. 625, New York, NY 10011

HERBICIDE INJURY SYMPTOMS AND DIAGNOSIS. North Carolina State University.

FERTILIZERS: DEFICIENCIES & TOXICITIES

DIAGNOSTIC TECHNIQUES FOR SOILS AND CROPS. 1948. Published by the American Potash Institute, Washington, D.C.

WESTERN FERTILIZER HANDBOOK. Order from: The Interstate Printers and Publishers, Inc., Danville, Illinois 61832.

DIAGNOSTIC CRITERIA FOR PLANTS AND SOILS. 1966. Edited by Homer D. Chapman. Published by University of California Division of Agricultural Sciences. 793 pages. Includes function of the element in the plant, plant symptoms of deficiency and excess amounts of the element, diagnostic concentrations of the element in plant tissue and soil. Includes the major as well as trace elements and a chapter on organic soil toxins. This book is in the OSU Kerr Library, S593, C48.

SOILS

MANUAL FOR JUDGING OREGON SOILS, Oregon State University Extension Service Manual 6 (September 1984). J.H. Huddelston and G.F. Kling. Available for $7.50 from: Bulletin Mailing Service, Oregon State University, Corvallis, OR 97331. Make check payable to: Oregon State University.

This 81-page manual is a good introduction to Oregon soils and a guide to evaluating and judging specific soils. The chapters on Properties of Soil Horizons (soil colors, mottling, texture, structure), Properties of the Whole Soil (effective rooting depth, water-holding capacity, permeability, erosion potential, drainage), Site Characteristics (slope, landform), and Management Interpretations guide the landowner in acquiring more information and understanding of the soil. The manual was primarily designed as a guide to students preparing for soil judging contests, and it is equally valuable to others who evaluate soils.
