THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION
Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences

Diagnostics System for Crop History and Disorders in Greenhouses and Nurseries

CONTENTS

Diagnostics Systems for Greenhouses and Nurseries

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Read This First!

This manual has been put together based upon consultation with Extension specialists and industry consultants with a great body of experience. Hundreds of greenhouse problems, and our experience with hundreds of business owners (as well as their responses to problems and the outcomes) have provided much insight into the best ways to handle problems, especially large scale losses. Based upon this experience, we recommend that each business owner decide in advance of implementation: 1) Who will be in charge of developing the records and documents required to maintain the information required for this system to work, and 2) Which management person will be given the ultimate responsibility/accountability for overseeing the diagnostic process, reporting the findings, implementing the recommendations from the owner/board, and finally, documenting the outcomes.

In general, the owners of most businesses (even small businesses with only five or more full time employees) are the least efficient people to handle the duties of record keeping, and absolutely the worst possible choice for handling the responsibilities of problem diagnosis. Ignoring the obvious impact an owner inquest has on employee morale, a major point to consider is how spending time on problem diagnosis might affect ongoing business. Most owners cannot afford to drop everything and dive into a production problem, although their emotions and attachments tell them to do so. The owner should be the one receiving the reports, taking recommendations from the staff, and formulating a response to the problem(s) based upon facts and recommendations. The likelihood the diagnosis will be carried out in a consistent manner increases dramatically by making this work a formal part of a manager's duties, or by hiring a qualified consultant, rather than the owner taking on the work. This strategy also keeps the owner out of the emotional stresses problem diagnosis can generate. By keeping a clear mind and some distance from the problem diagnosis process, rational and effective decisions are more easily made. Owners will also find reading this document a bit easier if they decide in advance this is not work they will have to incorporate into their busy schedules. We respectfully offer this advice as perhaps the most important issue to be considered within this document.

The Importance of a Procedural Diagnostic System

Most crop problems can be minimized or avoided, and overall costs dramatically reduced, if the evaluation and management of problems encountered during crop production is expedited. This involves an integrated, two-pronged strategy: 1) growers must be able to rapidly self-diagnose and treat common problems in advance of seeking professional assistance; and 2) growers must implement a systematic, detailed history to provide crucial information about past crop production as well as helping it determine the cause for other problems.

With detailed crop history records, growers can review long-term trends that are involved in crop problems because of a local factor (e.g., low water quality) or external factors (e.g., low quality of plant material, fertilizers or growing media). If detailed crop records are kept and a cost estimate of a recurring problem is made, growers may be more willing to address the causal factor. In addition, a crop problem may have

developed because of neglect or error on the part of an employee. For example, workers may not have been adequately trained to recognize the symptoms of a developing plant problem and/or apply proper terms to describe it. Lack of proper training and/or communication is often unrecognized, and can exacerbate the situation. If not dealt with at the source, such problems may occur repeatedly.

If an outside extension specialist or consultant is brought in it is always very helpful, and often essential, for the information describing the problem and all related data to be made available in advance, before anyone arrives on-site. If the crop information is thorough and sufficient, a visit by a consultant may not even be necessary, saving the grower time and money. A principal bene-fit of using a procedural diagnostic system with grower-provided data is that completing the form requires the producer to record environmental ele-ments, cultural procedures, chemical treatments, and other factors used in the production cycle. Frequently, a grower will suspect a particular factor when he or she has completed the form simply from being forced to review and outline the crop production program. This data can then be saved and accessed for future review when a problem arises.

Much diagnostic work and preventative maintenance monitoring can be done by greenhouse/nursery personnel, preferably several employees who work with plants on a day-to-day basis in the production areas. The person or persons charged with production quality control must observe and survey plants on a regular schedule, daily if possible. Details such as needs for watering may require more frequent inspec-tion. Unnecessary losses are encountered too often due to infrequent checks for infestations of pests, pathogens, or other factors. Heavy losses can usually be avoided if problems are detected early and corrective measures initiated quickly.

Crop records and images of plant problems also are essential in disputes with suppliers, shipping agents, or customers. A compilation of diagnostic information over time will provide the producer with an invaluable database for solving future problems while increasing his or her credibility with business associates, customers and government officials.

Understanding Serious Plant Production Problems

Understanding of chronic or large-scale plant problems is a challenging task that requires three things: 1) knowledge of expected plant growth processes and an understanding of environmental factor influences (light, temperature, moisture, nutrition, gases, plant pests, pollutants, and other agents) can have on plant growth and quality; 2) knowledge of the immediate circumstances surrounding the problem, and a review of any historic records; 3) and thorough understanding of the company structure, its market, and the employer's supervisory policies and procedures. Whereas most greenhouse problems will not require you to use this entire form, when a serious problem does arise, you will need to answer the entire set of questions so that consultants, Extension Specialists and company representatives can properly understand the larger picture and formulate a proper response or recommendation. Most chronic problems are solvable only by a major, well-planned change in management procedures or policies.

The Diagnosis Procedure

In order to perform basic plant examinations, environment assessments and soil tests, you will need the following equipment:

1. pH (meausres acidity of the soil solution) and Electrical Conductivity (EC) testing equip ment (measures soluble salts in the soil solu tion)

2. pH and EC calibration solutions

3. Light meter (you may also use a photo graphic camera to estimate light levels)

4. Hand lens (10x or 20x power)

5. Soil thermometer

6. Digital camera

7. Standard razor blades for dissection

8. Crop problem forms (provided below)

9. Water tray/saucers for capturing soil leach are measured with the Pour Through technique

10. Soil test bags for soil samples (can be ob tained from local county extension agent of fice)

11. Paper bags for tissue samples

12. Large, heavy-duty bags for whole plant samples

13. Clean plastic sealable bottles for water samples (available from testing laboratories)

Plant Examination

Injury from a specific pest, presence of a pest, expression of dis-ease, phytotoxicity symptoms, or evidence of mechanical injury often is so obvious on aerial plant parts that no further inspection is necessary to properly identify the problem. Where symptoms on aerial plant parts alone do not provide sufficient clues to the cause of the disorder, the basal portion of the stem and the root system should be examined. Plants with an underdeveloped or partially destroyed root system rarely have vigor-ous top growth, and, conversely, plants may have excellent root systems but due to some injury, nutritional imbalance, or other limiting en-vironmental factor, may be stunted or fail to develop normal foliage or stems. A dissection kit is needed to look for vascular diseases. A hand lens with 10 to 20 power is usually sufficient to identify many major pests and disease problems. You may also need paper bags to collect samples for shipping.

Light

Major fluctuations in weather or changes in climate (due to chang-ing seasons or other climatological events) should be considered when diagnosing plant problems. Shade level of a structural cover must be changed for some crops from winter to summer, and vice versa, to maximize growth and retain plant quality. As light levels increase during the spring months, many growers find a number of plants injured from excessively bright light under structures when shade was not increased to compensate for increased external light levels. Others experience poor growth during winter months because summer shading levels were maintained during lower light levels in winter. Growers should have at their disposal a light meter that measures incident light and reads directly in footcandles or lux units. An incident light meter with a range up to 10,000 footcandles is adequate for use in production structures. An expanded range permits the meter to be used under full sun in areas where light intensity exceeds 10,000 footcandles.

Temperature

Temperature regulation is critical for maintenance of healthy plants. Injuries may be caused by excessively high temperature from ventilation and/or cooling system failure or when plants are elevated where temperatures are higher than levels where most plants are grown, such as hanging baskets. Plants subjected to above-optimal temperatures are often stunted and, when combined with excessively high light levels, may become chlorotic. Leaves of sensitive plants may partially collapse and/or develop leaf scorch from the combined influences of high temperature and excessive light. Cold injury occurs when structures are improperly engineered to provide sufficient heat during cold weather, when heating or air circulation systems fail, when cold-water condensate drips onto plants from greenhouse roofs, when cold water is used for irrigation, or when plants are not properly protected from low temperatures during shipment or relocation within a nursery. Slight chilling is often difficult to diagnose; it may stunt growth thus interfering with production schedules. Growers should measure temperatures within structures at crop level and keep thermometers and thermostats accurately calibrated.

Temperature problems are often an issue at night. High-low or recording thermometers should be used since personnel may not be available to inspect houses in the dark. With crops that are intolerant to low temperatures or irregular where cold weather is common, an alarm system with a telephone interface may be good investment.

An independent soil thermometer may be necessary to obtain soil temperatures of the root zone. For plants

in larger containers, growers should take care to insert the soil thermometer to the appropriate depth to reach the root system.

Nutrition, Substrate pH and Salinity, Water Quality

Factors contributing to changes in substrate salinity (soluble salts concentration) and pH are the amount and type of fertilizer applied, amount and quality of water used, and quality of growing medium employed. Many nurseries routinely monitor soil fertility in-house because soil mix can be tested easily for salinity and pH with a test such as the Pour Through (Virginia Tech extraction method [VTEM or pour-thru method (Yeager et al., 1997)]. The grower or employee assigned to monitor these parameters can quickly determine if total soluble salts or irrigation water pH or substrate pH are within acceptable limits with a few basic instruments. A good quality pH and EC meter is essential in the greenhouse. However, even the best quality meter may give erroneous measurements if not kept calibrated. Therefore, growers and employees not only have to keep calibration solutions on hand, but also make sure that they have not expired.

Water quality can be tested in-house with a kit, or a sample can be sent to a professional lab. An important aspect of water quality, which is often overlooked, is alkalinity. This information is essential to determine if acid injection is necessary to bring the pH of the irrigation water within a desirable range.

Over- or under- fertilized crops can result from a malfunctioning fertilizer injector. This equipment must be kept calibrated according to manufacturer recommendations. Periodic check of the fertilizer solution with EC meter will detect malfunction.

Phytotoxicity

Reduction in plant growth and blemishes that lessen product qual-ity are always possibilities when agricultural chemicals are applied to crops. Only products that are labeled for ornamental crops and tested under greenhouse conditions should be used. Accurate records of materials used, their con-centrations, and other factors will assist in linking a specific injury symp-tom to the use of a particular fertilizer, pesticide, or other chemical. If the media, fertilizer, pesticide or other chemicals are suspected of causing a crop problem, it is essential to save an unopened bag of the product having the same lot number. Have it available when the local Department of Agriculture inspector pays a visit. Samples of affected crops also should be saved for diagnostic purposes. Records of chemical applications should be kept on hand.

Air Pollution

Occasionally, greenhouse operators encounter air pollution prob-lems caused by heating unit malfunction. Ethylene is usually the primary gas responsible for pollution injury. Relatively inex-pensive kits are available that measure ethylene, propylene and acetylene concen-trations in parts per million. Kits of this type are often used in deep mines where dangerous gases accumulate and are sold through many safety supply firms. Sampling of greenhouse air for toxic components should be done on cool nights when structures are closed and heaters are operating. Crop injury from pollutants originating outside growing areas may be difficult to prove. Assistance from local Cooperative Extension Agents, pollution control agencies at state and national levels, local meteorologists, and independent consultants may be necessary to as-sociate and document such occurrences. The local gas company phone number should be available in an accessible location in the greenhouse.

How to Use This Procedural Diagnostic System

This diagnostic system is designed as a tool to assist growers, Extension Specialists and county agents to diagnose problems with ornamental crops. The document consists of six major sections and five appendices. Each section is designed to supply information on various important aspects of the crop under scrutiny.

Part I. Company Background. The purpose of this section is to identify the company's structure and to provide information about the job responsibilities of each employee involved in crop production, including managers and supervisors, and their level of training. Internal communication practices such as job descrip-

tion and skill expectations affect performance and are often the cause of many misunderstandings.

Part II. Greenhouse Environment. The purpose of this section is to gain information about the pro-duction location (growing facilities) and all aspects of the crop environment both inside and outside greenhouse.

Part III. Crop Information. This section includes sources of plant material (seeds, plugs, cuttings, liners, etc.), health condition of material upon arrival, date of planting, time in production, etc. Questions pertaining to environmental factors (light, air and soil temperatures, air movement, and humidity) and cultural factors and practices (substrate, irrigation, nutrition, growth control measures, pesticide application) are included. Finally, post-harvest questions to determine if shipping or cultural conditions affected product performance.

Part IV. Symptom Identification. This section contains a comprehensive checklist of symptoms, allowing the grower to quickly pinpoint which part(s) of the plant are affected, type of damage and pattern across the crop.

Part V. Testing Results. Results of specific on-site testing such as pH, EC, and tests for fertilizer injector calibration are included.

Part VI. Digital Images of Growing Area, Affected Crop(s), and Symptoms.
Digital photography can be very helpful in crop diagnostics. Growers need to be thoroughly familiar with their digital cameras, i.e. how to change various settings to compensate for different light conditions. This part contains explanations of some simple rules to ensure the best picture results for accurate and rapid diagnosis.

Appendix I. Submission Procedures for Media, Water, Fertilizer, and Plant Tissue Samples. This appendix describes the proper procedures for obtaining, handling and submitting samples of growing media, water, and tissue samples for lab analysis.

Appendix II. Glossary of Terms Used to Describe Symptoms of Plant Disorders. This appendix consists of a list of terms used by trained horticulturists that can be utilized to describe plant disorder symptoms.

Appendix III. Diagnostic Key for Common Plant Disorders. The purpose of this key is to assist growers and employees in identification of likely causes of the crop problem, help them eliminate unlikely causes, or to re-direct attention to management weaknesses.

Appendix IV. Digital Images Applications in Crop Diagnostics. High quality digital images with sufficient information are essential to properly diagnose the plant problem. Seven important steps with examples are described in this appendix to help the grower obtain the necessary digital information.
Appendix V. List of Important Contacts.

Forms

1. Company Background

2. Greenhouse/Nursery Environment

3. Crop Information

4. Symptom Identification

5. Testing Results

6. Digital Images of Growing Area & Crops

7. Request for Crop Problem Diagnosis

8. Important Local Contact Numbers

Appendix I. Submission Procedures

(adapted from Horticulture Information Leaflet 580. 1998. North Carolina Cooperative Extension Service)

Media Substrate

Testing frequency. Every 3 to 4 weeks or whenever a problem has occurred.

Routine tests. Standard analysis should include pH, EC, NO3-N, NH4-N, P, K, Ca, and Mg.

Suspected micronutrient imbalance. In cases where micronutrient deficiencies or toxicities are suspected, test should include sulfur and micronutrients (S, B, Cu, Fe, Mn, Mo, Zn).

Procedure. The sample should be representative of the crop or problem to be analyzed.

1.Routine analysis. Samples should be collected from 5 to 10 pots and combined into one sample. Two ways to collect root substrate sample are as follows: a) A wedge-shaped piece from the top to the bottom of the pot is removed, excluding the top 1/2 inch of the substrate, or b) a handful of substrate from the center 1/3 of the pot is removed.

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2.Samples from all problem plants should be thoroughly mixed into one sample. All large roots and/or plant debris should be removed.

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3.Problem pots or benches should be sampled separately.

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4.Repeat sampling procedure for healthy plants of the same crop and place in a separate bag, labeled accordingly.

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5.One to two pints of root substrate is required for the analysis.

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6.Samples should be placed in a plastic bag, labeled with grower's name, greenhouse/nursery operation name and address, crop, and sample location.

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7.Samples should be collected in an identical manner in order to make valid comparisons of results and detect trends over time.

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8.Request "GREENHOUSE OR NURSERY TEST" on the sample bags. This will ensure that if the media contains slow-release fertilizer, it will be processed in a way to avoid false-high readings.

Procedure for testing new media substrate. If a test on a new substrate is desired, or substrate is mixed on site, samples should be submitted for routine analysis.

1.Fill a pot with the new substrate and irrigate to container capacity, i.e., until water drains from the container. After draining, the sample is placed in a plastic bag, labeled with the appropriate information, and mailed. Two days are required for the amendments to react with water so that accurate pH readings can be obtained.

Irrigation Water Testing

Testing frequency. Three to four times a year, if the same well is used. If a new well is drilled, the water should be sampled separately.

Routine tests. Standard analysis should include pH, EC, alkalinity, and hardness.

Macro- and micronutrients. In some instances test for N, P, K, Ca, Mg, S, B, Cl, Fe, Mn, Mo, and Zn is necessary. The irrigation water should be sampled for macro- and micronutrients at least once a year. If high sodium is suspected, the water should be tested.

Procedure.

1.Allow water to run for 5 minutes to clear the line.

2.Rinse a clean plastic 16 oz. container 2 to 3 times with the water to be tested.

3.Fill the container completely and cap tightly.

4.Label the bottle with appropriate information (name, address, type of analysis requested).

5.Sample should be mailed within 24 hours.

Soluble Fertilizer Water Testing

Testing frequency. Once a week on site; 3 to 4 times per year by commercial labs.

Routine tests. Standard analysis should include pH, EC, NO3-N, NH4-N, P, K, Ca, and Mg.

Procedure.

1.Accurately weigh the amount of fertilizer to be dissolved in the stock tank. Thoroughly mix fertilizer and water for complete dissolution.

2.Allow water to run for 5 minutes to obtain representative sample.

3.Rinse a clean plastic 16 oz. container 2 to 3 times with the fertilizer water to be tested.

4.Fill the container completely and cap tightly.

5.Label the bottle with appropriate information (name, address, type of analysis requested).

6.Sample should be mailed within 24 hours.

Plant Tissue Testing

Testing frequency. Once a month on site, or whenever a problem has occurred.

Routine tests. Standard analysis should include and macroelements (N, P, K, Ca, and Mg) and micronutrients (B, Cu, Fe, Mn, Mo, Zn).

Procedure. The sample should be representative of the crop or problem to be analyzed.

1.For routine analysis collect leaves from 20 to 30 plants (small-leaved plants will require more (approx. 70 leaves) and combine into one sample.

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2.Collect the most recently matured leaf (the first fully expanded leaf from the shoot tip).

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3.Remove the petioles from the leaves.

4.If sampling plugs, entire shoots are sampled. Collect the aboveground portion of 10 to 15 plants.
5.Problem plants or benches should be sampled separately.

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6.Healthy plants of the same crop should also be sampled for comparison purpose and placed in a separate bag.

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7.Make sure that leaves are free of soil, growing media or fertilizers. If surface contamination exists, or foliar nutrients were applied, gently rinse the leaves in distilled water (preferably, but tap water is acceptable) for 10 to 20 seconds to remove surface contaminants.

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8.Blot each leaf dry before packaging for mailing. Never pack wet leaves.

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9.Place the leaves in a paper bag (to discourage leaf molds from destroying the sample) or other suitable container. Label the bag with appropriate information (name, address, crop, location of sample).

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10.Sample should be mailed within 24 hours. Effort should be made to collect the sample in the beginning of the week so it would not be delayed over the weekend.

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11.Samples should be collected in an identical manner in order to make valid comparisons of results and detect trends over time.

Appendix II. Glossary of Terms Used to Describe Symptoms of Plant Disorders

(adapted from Henley. R.W. 1981. Diagnosing Plant Disorders. In: "Foliage Plant Production" Ed. J. Joiner. Prentice-Hall, Inc.)

For a proper diagnosis it is helpful to describe the plant problems in terms used by trained horticulturists. The following is a partial list of terms that you can use to describe disorder symptoms.

Atypical leaf shape: Leaves that are distorted or mis-

shapen due to phytotoxicity, pests, nutritional disorders, or environmental factors.

Blight: Diseases caused by pathogens that kill primarily new expanding tissues of shoots and young leaves. Most blights are attributed to fungal and bacterial pathogens.

Blotch: Irregular spot diseases that vary in shape and lack a clean line of demarcation between infected and healthy tissue.

Burn: A non-technical term applied to a variety of injury symptoms induced by pesticide sprays, excessive light, excessive fertilizer, excessively high temperatures and pollutants.

Canker: Commonly localized, sunken lesions on stems that may crack open as they develop. Most cankers are caused by fungi or bacteria.

Chlorosis: The lack of chlorophyll in plant tissue, usually the foliage, resulting in an abnormal light green to yellow coloration. Caused by nutrient imbalances, root rots, insect or mite feeding, excessive light, chilling injury, or phytotoxicity from pesticides or pollutants.

Damping-off: The decay of seeds or roots and/or stems of seedlings near the soil line. Usually caused by soil-borne fungi.

Decay: A broad term that describes breakdown of tissues caused primarily by fungi and bacteria.

Defoliation: Loss of leaves caused by a number of factors, including root rots, insufficient or excessive water in the growing medium, low fertility, pesticides, wounding, high atmospheric ethylene or other toxic gases, and chilling.

Dieback: A condition where shoots are killed back by varying degrees depending upon severity of injury or disease infestation. Most dieback of pathogenic origin is caused by fungi or bacteria.

Dwarfing: A non-technical term that refers to restriction of plant growth, usually through manipulation of cultural procedures. Pruning, restriction of root zone, and withholding nutrients or water will dwarf most plants when done individually or collectively. Chemical growth retardants or phytotoxic effects of pesticides may also dwarf plants.

Epinasty: Curled and contorted leaves and stems developed from plants that have been exposed to growth regulators such as 2,4-D, or ethylene gas or plants that have been fed upon by certain insects that induce abnormal growth. Epinasty also may be caused by pollutants.

Fasciation: Plant organs or axes that abnormally grow together or become flattened, resulting in an abnormally irregular, thickened configuration of such organs, such as stems, leaves, flowers, and fruits.

Gall: Swollen abnormal growths that assume a variety of shapes and sizes and can occur on practically any plant organ. Some galls are hollow; others are nearly solid tissue. They may be induced by various pests.

Gumosis: A condition within vascular systems of stems, usually caused by systemic bacterial or fungal pathogens, which causes a gum-like exudate to be emitted from stem surfaces.

Lesion: Wounds on plant surfaces, which are usually induced by disease-causing organisms, mechanical means, pests, or through contact with phytotoxic chemicals.

Mold: The development of fungal mycelia (thin, hair-like fungal tissue) and spores over the surface of infected tissues on decaying organic material.

Mosaic: An abnormal pattern of coloration usually expressed in the foliage, but also flowers and other plant organs. Most mosaics are caused by viruses or mycoplasma-like organisms and often result in reduced plant vigor.

Mottling: A stippled pattern of chlorosis, which often develops when leaves have hosted spider mites, leafhoppers, or thrips. Mottling can be induced from pesticide application, nutrient deficiencies, or exposure to pollutants.

Necrosis: Dead plant tissue caused by a variety of factors, including disease-causing organisms, pesticide

phytotoxicity, pollutants, certain pests, temperature extremes, nutrient imbalances, and others. Such tissue is usually tan, brown, or black in color.

Oedema: A physiological disorder that results when plants absorb water faster than it is lost through evapotranspiration, causing cells to swell and rupture soft tissues, often on the underside of foliage. Such wounds usually heal as cork-covered bumps or blisters.

Residue: Foreign material on plants, which often is sufficiently conspicuous to detract from plant quality. Residues originate from various sources, including pesticide sprays, especially wettable powder formulations, mineral deposits from irrigation, iron deposits, deposits due to iron and manganese bacteria, and aerial particulate matter.

Rot: Deterioration of plant tissue caused by a plant pathogen, usually a fungus or bacterium. Some rots are associated with foul odors; others are relatively odorless, depending on the pathogen involved.

Scorch: A collective term that includes necrotic areas usually caused by excessive light levels, often coupled with high temperatures, which destroys foliage and/or stem tissue.

Silvering or silver speckling: Areas in tissue where individual cells have died, or their cellular components been removed. Silvering refers to phytotoxic reaction often seen in plant tissue sensitive to air-applied chemicals. Also used when referring to spider mite damage.

Spindly vegetative growth: Describes plants grown under dark conditions that have stems that elongate excessively and become thin and weak. This is a non-technical term.

Spots: Caused by disease-causing organisms, primarily fungi and bacteria, chemical injury, and certain environmental factors. Spots vary in size, shape, and color and occur primarily on foliage and stems.

Stunts: Caused by specific systemic organisms such as fungi, bacteria, and viruses that reduce the rate of water and nutrient movement within infected plants, and drastically slow growth.

Wilt: Caused by loss of turgor in plant tissues due to inability of roots to take up water. Plants that have blocked vascular tissues by systemic plant pathogens have a category of diseases known as wilt. Wilting also results from moisture stress or excess soluble salts in the growing medium.

Witches' broom: A condition that results in proliferation of shoots from specific regions of a stem. It can be caused by pathogens on some hosts, insects and mites on others, and by boron or copper deficiencies.

Appendix III. Diagnostic Key for Common Plant Disorders

Symptoms Description:	Possible Cause:
Problems Involving the Entire Crop with or without Pattern (Indoors or Outdoors)	
Pattern consistent along rows, sides of a bench or on the same side of plants.	Improper Pesticide or Fertilizer Application, Spray Drift
Pattern in a circular or semi-circular area, primarily seen outdoors.	Lightening, Nematodes, Pesticide Spill, Disease
Pattern irregular, in large or small groups.	Soggy Ground, Pesticide Spills, Pests, Animals Seed, Plant Genetics, Diseases
No pattern, extensive, seen on entire crop.	Review All Crop Applications / Irrigations, Weather Data, Diseases

Problems Involving the Whole Plant with Normal Shape Leaves and Stems	
A. Leaves appear normal, growing poorly, slowly, significant parts of plant are chlorotic, plant appears deficient. (Also: check roots for damage)	
Upper 1/3 of plant (new growth) is chlorotic, off-color or stunted.	Trace Element Imbalances, Light Levels
Lower 1/3 of plant (older leaves) chlorotic, purpled, bronzed.	Trace Element, Imbalances, likely Mg, K, P, Fe, Mn, or, B, Light Levels
Only lower 1/3 leaves necrotic, aborted / dropped. (Also: Check roots for disease)	Low Light, Spacing, Temperature, Irrigation
Leaves from most of the plant aborted/ dropped off, freen or light green, new leaves stunted, cupped, off-shape.	Ethylene, Propane, Natural Gas and Other Petroleum Volatiless
AA. Leaves appear normal; discrete parts of plant are off-color or wilted.	
B. A small portion of the leaf has a discoloration and/or is wilted.	
Leaf margin is yellow or white on many older leaves.	Cycocel, Excess Fertility
Small portions of the leaf margin are yellow or necrotic, occasionally mid-leaf sections are yellow, necrotic or tan. Pattern is irregular, usually where liquid collects on leaf. Plant continues to grow. New leaves appear normal.	Mild Phytotoxicity (Short term or minor)
Leaf has a few too many small round dark brown, purple spots or wavy tan/black patterns of necrotic tissue. Problem appears to be spreading or getting worse.	Disease
Entire plant or many leaves wilt, turn dark black-green, Semi-transparent to light, then plants die within 48 hours.	Surfactant, Soaps, Oils, Chlorine Compounds, *Bleach, Bromine), Severe Phytotoxicity, Freeze Injury
BB. Overall leaf color is abnormal, bronzed, bleached, blackened, cleared or purpled.	
Entire plant pale green, poor growth with some yellowing at the margins, few blooms, small flowers. *Check roots for damage.)	Fungicides, Herbicides, Nutritional Deficiencies (N, S, Fe)
Entire plant or most leaves yellow, leaves twist, cup and change color to bronze or purpling. Tissue turns necrotic, plant is stunted , or grows excessively slow; often dies in 3 to 10 days. (Check roots for damage.)	Herbicide
Overall plant is very chlorotic, leaves may be bright yellow with tan or necrotic zones. (Check roots for damage.)	Sunscald, Excess Heat
AAA. Plant with elongated stems, floppy or weak-stemmed (stems split or break), leaf color pale.	
B. Plants are chlorotic or look weak, root development very poor.	

New growth is chlorotic, very leggy, grows fast, flowers normal, or smaller and very early (precocious).	Heat Stress
Plants are chlorotic, leggy, grows and flowers poorly, few new roots develop. (Check roots for damage.)	Over-watering, Nitrogen Imbalance
Plant, or group of plants wilts suddenly, dies rapidly. (Check roots for damage.)	Lightening from sky, Propane, Diseases, Boring Insects
BB. Plants are dark green, root development moderate to good.	
Plants are bright green, soft, leggy and flower poorly.	Excess ammonium/phosphate, Low Light
Plants are hard, dark green, gray-green, and/or tinged in purple or bronze, stems very compact, plants growing slowly, if any. Slow flowering, stunted peduncles.	Cold Stress
Plants are yellow-green, cupped, compact and slow-growing. Flowers early or absent, quality very poor. Leaves with white patches, and/or necrotic spots in center of leaf.	Excess Light
Plants appear healthy, stems splitting or breaking, weak.	Improper Crop Spacing, Night Temperature
BBB. Plant leaves scraped, marked, streaked, shredded or with slits and rips.	Hail, Wind Damage, Mechanical Damage
BBBB. One or few stems wilt, the remaining plant appears turgid and healthy.	Disease, Physical Damage from humans, animals or machinery
Problems Involving the Leaves	
A. Leaf shape abnormal, twisted, or physically damaged stems, internodes normal.	
B. Leaf is dark green to yellow-green with abnormal color patches.	
Leaf yellow with irregular dark purple/bronze spots or pitted. Problem appears to spread or expand. (Check roots for damage.)	Herbicide, Disease
Streaks, leaf creases, and small spots that are light tan, white tissue may turn necrotic, limited spread.	Wind, Fan Draft
Tiny spots, holes, stippling, or chewing evident. Leaves curled or distorted, skeletonized.	Insects, Pests (slugs)
Leaves blackened, transparent and wilted.	Surfacants
BB. Leaf twisted and/or variegated, with white, gray or yellow tissues.	
Leaf has normal shape, few leaves variegated on plant.	Genetic (Cell Mutations)
Leaf abnormal, twisted, margins feathery or finger-like. Irregularly variegated, episodic, transient, usually in warm season. Symptoms vanish under high fertility.	Virus, Herbicide (Mottle Pansy Syndrome)
Leaf/stem abnormal, twisted, cupped, chlorotic, necrotic.	Herbicides, Spray Damage, Light Levels, Temperature

BBB. Leaf dark green, stunted, tight rosette, no or slow growth	
New leaves cupped, very stunted, tip growth absent or bunched up. New leaves poorly formed.	Boron Deficiency
Leaves increasingly smaller, normal but few flowers. No new growth for weeks. Leaves abnormally dark, or cupped. Internodes very short, new growth bunched in rosette.	Excessive application, Rates of PGRs (PGR Toxicity)
Old leaves normal, newer leaves becomes cupped, flower buds drop/dry up. New growth may resume normal. (Check roots for damage.)	Gas, Exhaust
AA. Leaf shape and stem internodes normal, but leaves off-color or have spots.	
B. Leaf color in a small portion of the leaf is abnormal:	
Leaf margin is yellow or white on many older leaves.	Cycocel, Excess Fertility
Small portions of the leaf margin are yellow or necrotic, occasionally, mid-leaf sections are yellow, necrotic or tan. Pattern is irregular, usually where liquid collects on leaf. Plant continues to grow. New leaves appear normal.	Chemical Phytotoxicity
Leaf has few to many small round, dark-brown, purple spots or wavy tan/black patterns of necrotic tissue. Problem appears to spread or get worse over time.	Disease, Pests
BB. Overall leaf color is abnormal.	
Entire plant pale green, poor growth with some marginal yellow at the margins, few blooms, small flowers. (Check roots for damage.)	Fungicides, Herbicides, Nutritional Deficiencies
Entire plant or most leaves yellow, with central portions of the leaf affected, often dies within 3 to 10 days.	Herbicides / Sunscald
Entire plant or many leaves turn dark black-green, semi-transparent to light, wilt, then die within 48 hours.	Surfactant, Soaps, Oils, Chlorine, Petroleum Fuels
AAA. Leaf shape normal, however, stem internodes are very long or very short	
B. Plants are chlorotic or look weak, root development very poor.	
Plants are chlorotic, very leggy, grow fast, flowering normal.	Heat Stress
Plants are chlorotic, leggy, grow and flower poorly, few roots. (Check roots for damage.)	Excess Irrigation

BB. Plants are dark green, root development moderate to good.	
Plants are bright green, soft, leggy and flower poorly.	Excess ammonium, phosphate
Plants are hard, dark green, gray-green and/or tinged purple or bronze, stems very compact, plants grow slow, if any.	Cold Stress
AAAA. Leaf shape normal, stem internodes normal. Stems severed / broken at soil line.	
Tissue at cut brown or tan, or light green, but discoloration limited to immediate line or severance. Edges rough, chewed or ragged.	Insects (Caterpillars, Worms)
Stem tips missing. Seed colyledons missing, damaged stem rough, ragged with necrosis or tan tissue limited to the immediate cut surface.	Mice, Rabbits, Insects
Stem tips present, cut or broken stem area brown or darkened, mushy. Stems mushy above and below break or bend. Grey, fuzzy material on leaf, lesions may be visible on stem, discoloration, scarring. Number of affected stems or leaves increases over time. (Check roots for damage. Check fertility levels.)	Disease
AAAAA. Leaf puckered or with expanded cells, galls, thickening of epidermis.	Pests, Virus
Problems Involving the Flowers	
A. Flower size color normal, but markings on petals, spots, damaged sepals or peduncles bent.	
Flowers streaked, tan or white, scratches, creases and tan blotches.	Wind Damage, Mechanical Damage
Flowers with ringed spots, oblong necrotic spots.	Chemical Damage, Disease, Virus
Flowers normal but petals look dried, peduncles bent over.	Propane / Ethylene
AA. Flowers appear small, off-type or off-color.	
Flowers appear normal but are smaller than type (variety) (Check roots for damage.)	N or P Deficiency, Fungicides, Disease or Genetic Flaws
Flower pattern broken, variegated, flower oddly shaped.	Virus, Herbicides, Genetic Flaws
Flower color or pattern unusual, or off-variety	Genetic Variation
AAA. Flowers normal color but distorted, cupped, spotted, or streaked.	*Thrips, Sucking Insects, Temperature, Irrigation Chemicals*
Problems Involving the Root System	
A. Roots are white, root hairs visible in some portion or all of the root system.	
Roots fine but primarily in top half of medium.	Excess Irrigation, Soil density too high
Roots healthy in lower half of pot, but no root hairs in upper half.	Excess Soluble Salts, Chemical Damage, Drought, Heat

AA. Roots are tan to brown, absent or decomposed. Root epidermis sloughs off leaving central stele.	Disease, Excess Heat, Excess Irrigation, Excess Fertilization, Chemical Toxicity
AAA. Roots are specked, salt and pepper, plants increasingly chlorotic.	Disease
AAAA. Roots normal on two three sides cube forth side brown or sparse. (Verify sample obtained from external row or outer portion of flat, tray, aisle)	Heat, Sunscald
AAAAA. Root tips normal, root growth excessive, massive and fill pot/cell space. Plant growth slow, some chlorosis, cupped leaves or early flowering.	Root Binding, (Plants left in plug tray or pot too long)

Appendix IV. Digital Images Applications in Crop Diagnostics

Digital photography can be readily applied in crop diagnostics. Most crop problems can be minimized or avoided, and overall costs dramatically reduced, if the evaluation and management of these problems are expedited. This involves an integrated approach, first, growers must be able to rapidly self-diagnose and treat common problems in advance of seeking professional assistance; and second, growers must implement a systematic, detailed history to provide crucial information about past crop production deficiencies that are otherwise difficult or impossible to pinpoint. This is where digital images can prove helpful.

In documenting crop damage for example, growers may need to take a series of pictures to better illustrate the specific problem and provide sufficient information for diagnosis. Additionally, the higher the quality of the pictures, the greater are the chances of accurate and rapid diagnosis of the problem. Proper contrast and color rendition are essential in diagnosing some nutritional imbalances.

For optimal results in obtaining the best digital photographs, here are some simple rules to follow.

Reference Point. In this situation impatiens plugs have been kept for too long in the plug tray. To show height differences, place another plug tray behind to serve as reference point. Try to use some type of reference when illustrating growth differences between crops, cultivars (1).

Foliage Color. When photographing foliage or flower discolorations, e.g., resulting from nutrient imbalances, disease, etc., make sure you achieve sufficient contrast in the image. Chlorosis in lower foliage of celosia is accentuated by the green of other foliage (2a).

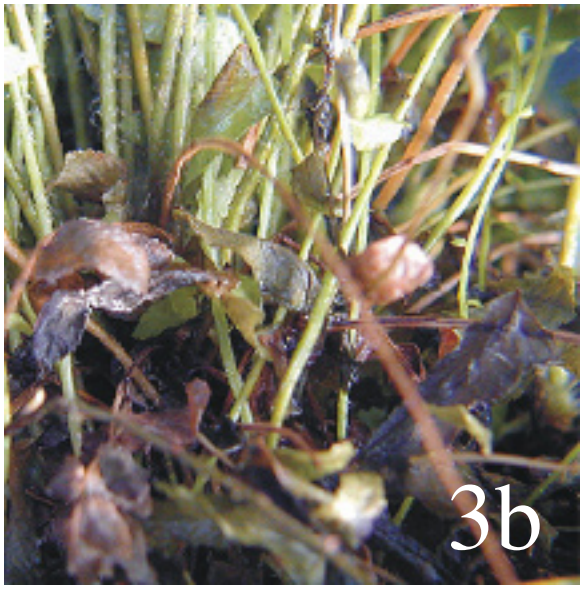
Similarly, a necrotic lesion in the New Guinea impatiens stands out in contrast with the healthy upper foliage (2b).

This image is too dark (2c).

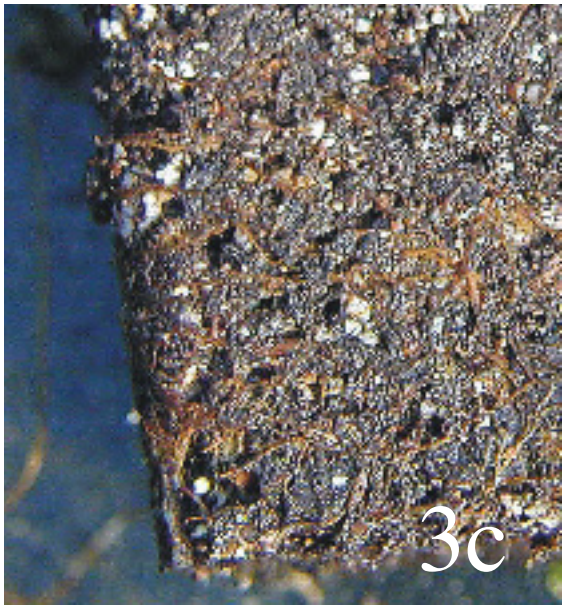
Some leaf surfaces are highly reflective because of their waxy cuticle. Consider increasing the exposure value (EV) setting. There is too much glare on the fern pinna. Consider moving the plant in a shadow or placing a screen in front of the bright light (2d).

Full complement of photographs to represent the 'entire picture'. The following series of digital images is an example of the type of photographs you should take for crop diagnostics. The problem occurred on Boston ferns grown in the early fall months. The symptom was foliar necrosis affecting the tips of the frond pinna (3a).

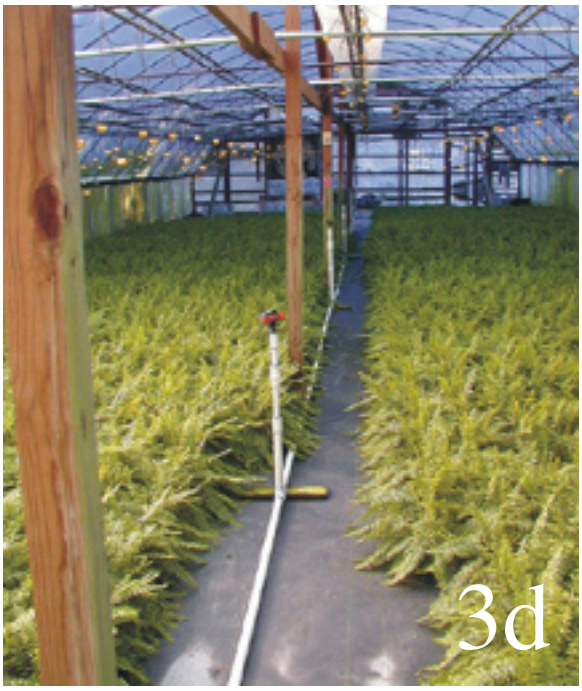
After visiting the operation and discussing cultural practices with the grower, we took a series of photographs, which were very helpful in diagnosing the problem.



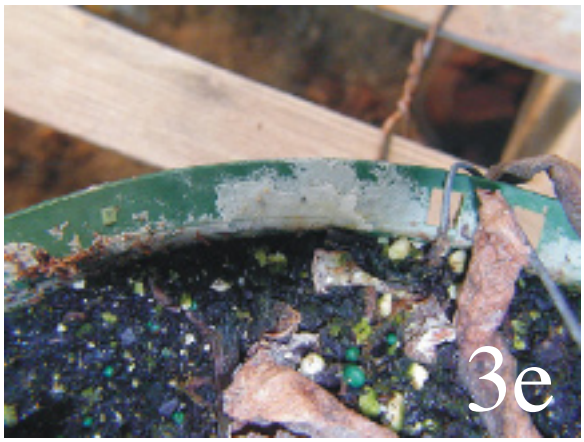
Close-ups of the foliar necrosis and the damage to young developing fronds (3b).



The root system also was damaged, as evidenced by the brown coloration and lack of healthy feeder roots (3c).

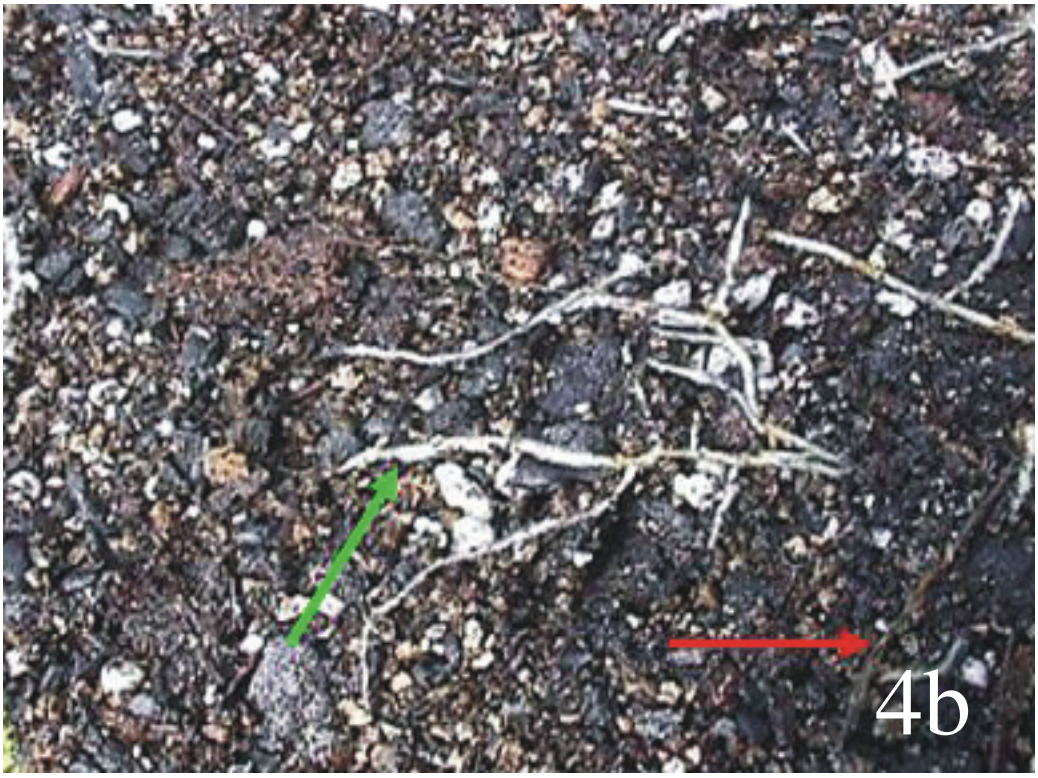


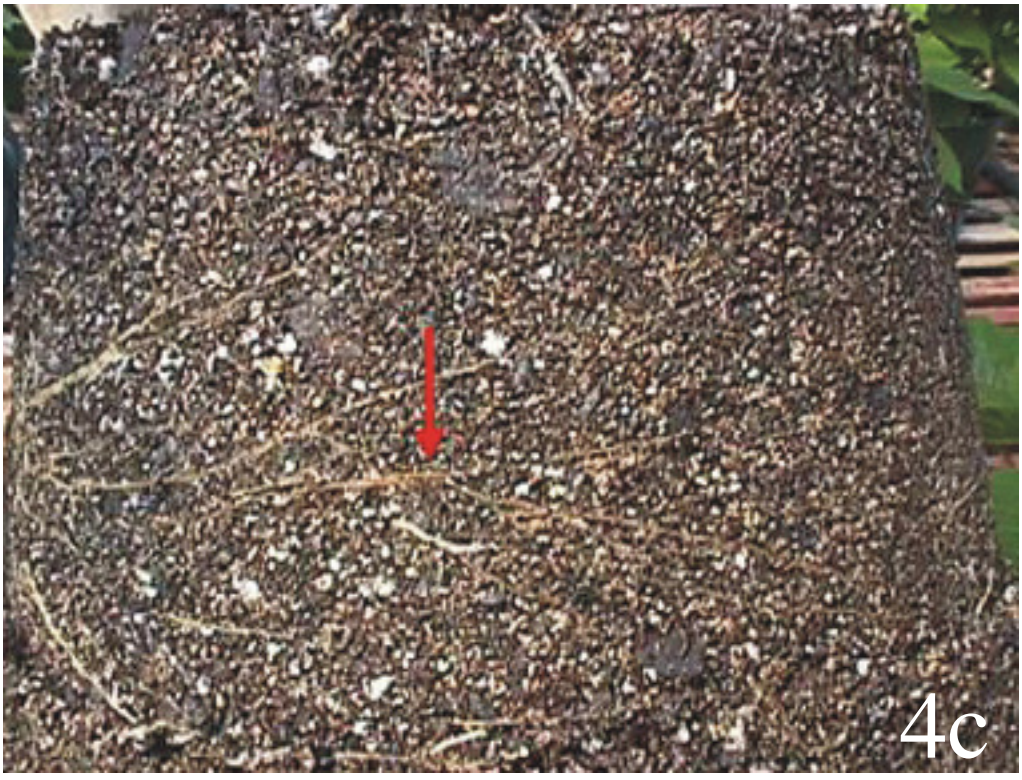
Following the symptoms on the crop, we took a picture of the greenhouse where the Boston ferns were grown (3d). This helped us visualize and document the growing conditions. For example, the crop was grown on a covered floor with pot-to-pot spacing, and it was irrigated overhead. In addition, from that photograph, we were able to make inferences about light levels in the greenhouse.



The symptoms were indicative of overfertilization, and when tests were performed, excess fertility was found in the growing medium. In searching for more 'clues', we found a white crust around the rim of some pots, also indicative of excessive fertilizer applied to the crop (3e).

Photograph healthy and damaged plant tissues. In this example, a poinsettia crop was exhibiting poor growth with some wilting. A grower sent us a picture of the root system, both overall and a close-up (4a-c). Although healthy white roots are present, the extent of the root system development is not satisfactory for the stage of the crop. Further examination of the root system reveals more severe root death (brown roots). The cause of the problem was identified as Pythium root rot.





Healthy roots are white (green arrow, 4b), while diseased roots are brown (red arrow, 4b-c).

Photograph the underside of leaves. Some disorders are expressed on the undersides of the foliage. For example, oedema in geraniums is a physiological disorder, which is manifested by hardened tissue appearing as corky, tan blisters on the foliage. The symptoms are commonly found on the undersides of leaves (5a).

Insect pests, as well as some disease symptoms also are found on leaf undersides. For example, whitefly larva are found on the undersides of leaves (5b).

Detecting a pattern of damage across the crop. If multiple plants show symptoms of damage/problem, take a photograph of the bed/area. This will give an indication of the spread of the damage and any possible patterns across the crop. In this example, chlorotic plants and leaves were seen throughout the vinca (6a).

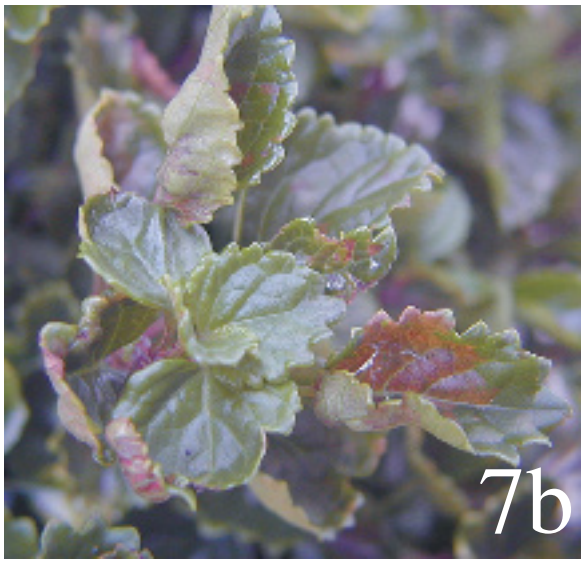
The symptoms and their pattern suggested a root disease. However, on closer inspection and when several young plants were extracted from the rooting medium, it was evident that the problem was caused by improper planting technique (6b).

The characteristic "J" hook occurs during planting when a person pushes the root system of the plug into the medium with their thumb, thus applying too much pressure on the fragile root system (6c). Often the epidermis on the side of the stem is damaged by the thumb's fingernail. The damaged root system rarely recovers to adequately support growth of the young plant. Hence, plants suffer from lack of nutrition and water and lag behind the rest of the crop.

The grower can go back and look in the planting records to find out the employee who planted the crop and correct his/her planting technique.

Use a macro lens for close-up pictures. When photographing symptoms on plants with small-sized foliage, or when you want to take close-ups, it is best to use a macro lens, or a respective macro setting on your digital camera that allows you to take a photograph of the symptoms filling the entire field of view (7a-d).

Close-up of powdery mildew on foliage of Salvia (7a). Necrotic brown lesions on Plectranthus caused by heat stress (7b). Notice that in both photographs the foliage is in sharp focus while the background is not. This is called shallow depth of field and is characteristic of photographs taken with a macro lens.



Using a macro lens allows you to photograph minor variations in foliage color as in the phosphorus-deficient leaves of Tibouchina (7c), as well as small specks, dots, etc., as in the poinsettia bract showing oedema symptoms, tan and brown specks, arrow (7d).

In summary, digital photography can be very helpful in crop diagnostics. Growers need to be thoroughly familiar with their cameras, i.e. how to change various settings, and follow basic rules of photography. You also need to follow some rules in order to obtain the best results and ensure accurate and rapid diagnosis. This is essential when pictures are sent to a county agent, extension specialists, or outside consultants.

Appendix V. List of Important Contacts

Pesticide Information

National Pesticide Telecommunications Network (NPTN), Oregon State University — General information on toxicology, environment hazard, etc. (M-F, 9:30 a.m.-7:30 p.m. EST) **(800) 858-7378**

Pesticide Manufacturer - The telephone number should be listed on the pesticide label

American Crop Protection Association - General information about the pesticide industry (MCF, 9:00 a.m.-5:00 p.m. EST)	**(202) 296-1585**
Chemtrec Referral Center - Refers caller to the company responsible for the pesticide (MCF, 9:00 a.m.-6:00 p.m. EST)	**(800) 262-8200**
National Response Center - Refers caller to proper government agency for hazardous materials	**(800) 424-8802**
EPA Hazardous Waster Hotline (Superfund)	**(800) 424-9346**

Hazard Communication

OSHA	**(404) 562-2300**
National Poison Control Center	**(800) 222-1227**

Web Sites with Pesticide Information

Self Test for General Standards Pesticide Exam	http://ianrwww.unl.edu/ianr/pat/pat.htm
Pesticide Action Network North America	http://www.panna.org/
CropLife America	http://www.croplifeamerica.org/
Extension Toxicology Network	http://ace.orst.edu/info/extoxnet
National Pesticide Telecommunications Network	http://ace.orst.edu/info/nptn/
NSF Center for Integrated Pest Management	http://cipm.ncsu.edu/
EPA Pesticide Product Information	http://www.epa.gov/pesticides/
EPA List of Restricted-Use Pesticide	http://www.epa.gov/docs/RestProd
EPA Pesticide Safety Programs/Worker Protection Standard	http://www.epa.gov/pesticides/health/worker.htm
EPA Office of Pesticide Programs	http://www.epa.gov/pesticides/local/
USDA	http://www.usda.gov/

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