Diagnosing and Managing Non-Pathogenic Disorders in Production Nurseries

SUMMARY

Abiotic disorders are caused by non-living factors and can be amongst the most difficult to pinpoint. Unlike many vegetable lines, most orgamental nursery lines are poorly characterised when it comes to symptoms of nutrient deficiencies, pesticide toxicity, adverse environmental conditions and the effect of other abiotic factors. Therefore, in most cases, managers of nursery stock must combine investigative skill with careful observations to deduce what is affecting their plants.

This nursery paper is designed to cover two areas. First, a simple (but not necessarily easy) step-by-step process is discussed to assist nursery managers to identify the causal factor of poor or unusual plant growth suspected of being caused by an abiotic factor. Second, symptoms of common abiotic disorders that can affect a wide range of plant species are described.

Suspect heat damage of *Syngonium*

INTRODUCTION

Abiotic disorders are caused by non-living factors that negatively impact plant growth and development. Abiotic influences include under or oversupply of water, sunburn, poor drainage (low oxygen environment), temperature extremes (heat, frost or large changes in temperatures during the day/night), hail or mechanical damage (e.g. high wind or mechanical abrasion), chemical injury (caused by insecticide, fungicide or herbicide), nutrient toxicity or deficiency, extreme pH in water or growing media, high EC and other aspects of poor water quality.

Abiotic problems can arise even in the best managed nurseries and are sometimes unavoidable. The pattern of symptom development and expression is critical to the diagnosis. Generally, abiotic factors can be suspected if a very high percentage of the stock line (e.g. near 100%)

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are showing symptoms. Symptoms may suddenly appear, without any further development. They can sometimes appear on one or two varieties within a species, but may also simultaneously occur across unrelated species. There can also be a progressive development of symptoms.

An abiotic disorder can be challenging because it can be difficult to recognise the factor causing the symptom; many factors can potentially cause the same symptoms. Therefore distribution of the disorder and crop history are of critical importance when diagnosing an abiotic problem, discussed in Part 1. Common abiotic stresses that cause unusual symptoms are discussed in Part 2.

THE FOLLOWING LIST INCLUDES THE MOST COMMON FACTORS THAT CAUSE ABIOTIC DISORDERS:

- Genetic mutations/reversions/chimeras
- Graft incompatibility
- Varietal predisposition
- Low/high temperature
- Large temperature variations
- Drought/excessive moisture
- High relative humidity
- Physical damage, e.g. from hail/wind
- Nutrient toxicity/deficiency
- Media and or water pH/EC (which can interact to cause a nutrient deficiency)
- Other media properties, e.g. lox oxygen
- Herbicide/pesticide
- Light quality
- Planting practices, e.g. planting too deep, clumps of slow release fertiliser
- Poor water quality, e.g. high levels of chloramines, sulphites and other substances

PART 1. DEDUCING THE CAUSAL AGENT

The following steps can be used to assist in diagnosing abiotic problems. The point here is not to cover all possible situations, but to emphasise logic that can assist in determining the problem. Take the general process and apply it to your situation. Before you start, examine literature to ascertain if the plant or closely related species have information available showing symptoms that might be consistent with the specific problem. Look for the range of nutrient and environmental disorders that might be found online as well as pests and diseases. In addition, use your own knowledge of the plant and available information on optimal growing parameters. This can be used as a point of comparison when completing various strategies described below.

Steps 1–4 are investigatory, gaining detailed information about the crop and may be completed out of order. Steps 5–6 synthesise the information to provide next steps to trouble shoot the problem and hopefully establish (but at least rule out) the causal factor. Keep in mind that more than one factor may be impacting the crop or interacting to produce symptoms.

1. ASSESS THE PATTERN OF DAMAGE

As indicated above most abiotic problems impact entire crop lines at a very high incidence because, in general, these factors occur over the entire crop and even over wider geographical regions. Environmental conditions rarely affect a portion of the crop. Likewise, aspects of water quality affect the entire crop because all plants receive the same water. Examine the pattern of symptom development in all areas of the nursery where the line is grown. If the same line is grown in protected cropping and outside (perhaps in both containers and in-ground) it may provide clues. Likewise, if the problem only occurs in areas receiving water from a certain supply it could point to some aspect of water quality being the causal agent. Therefore, examine where the crop line is grown under differing conditions to gain pieces of information. Talk to other growers nearby who produce this crop and ascertain if they are also observing the symptoms. If all growers producing the line in the region are observing the same symptoms across many growing systems, it suggests that environmental conditions are the most likely causal agent.

2. DISSECT-EXAMINE WHOLE PLANT, ROOTS, VASCULAR TISSUE AND FOLIAGE

Examine the plant in detail using magnification, preferably using a dissecting microscope. In particular, look for small insects and mites (e.g. broad mites, thrips, mealybugs). Examine root health by lifting plants out of the pot, and wash roots to assess structure (e.g. J-roots or other extreme bends or kinks in roots and lower crown). Finally, cut the stem with a sharp knife down the stem to near ground level to examine cortical and vascular system health; the vascular system of healthy plants is generally light to dark green, varying with species. Dark brown streaks or regions in the vascular tissue are characteristic symptoms of an invasion by a vascular wilt pathogen. Note that exposed plant tissue oxidises, similar to a cut apple, and will turn brown over time; the fresh cut is critical. If disease symptoms are observed submit a sample to a diagnostic laboratory. This will determine if a pest or disease is present.

Vascular discolouration caused by *Fusarium* in a nursery cutting. In this case the discolouration is most severe below ground-level and less noticeable up the stem.

3. SUMMARISE HOW SYMPTOMS FIRST APPEARED – EXAMINE THE CROP HISTORY

If you record crop health parameters on a regular basis (which is highly recommended), examine these records when the problem occurred and also during the preceding 3 months. If symptoms appeared gradually it indicates that the factor has increased in intensity over time. This is often as a result of changing environmental conditions, but can just as easily be as a result of increasingly poor water quality or other factors that may change gradually over time. Problems that appear suddenly and did not spread could also be environmental, particularly if there was an extreme weather event. However it can also indicate that something toxic has been applied to the plant (knowingly or accidental). Where there is a series of plants of the crop line propagated at different times, examine them carefully for a possible pattern. This will help pinpoint when the predisposing factor was active. Examine motherstock plants or talk to your supplier to gain additional information (not to pin blame, just to gain additional information).

Bougainvillea propagated over a six week period. Cupping of leaves and deformed growth was evident from Time 1 and 2 that were 3 weeks apart (top two images), but not at Time 3 another 3 weeks later (bottom image). Damage was linked to poor water quality.

4. ASSESS WHAT THE PLANT NEEDS (PERSONAL EXPERIENCE AND AVAILABLE LITERATURE) AND WHAT IT IS ACTUALLY RECEIVING, E.G. LIGHT, WATER PH, EC, MEDIA REQUIREMENTS, NUTRIENT REGIME.

Complete as many tests as you can moderated by the practical and financial considerations. It is recommended that all growers test their water pH and EC at least weekly, more if results are variable. These are the first things to check if you have a problem. In addition, check the following:

- Examine chlorine levels (both free and total – a difference between the two may indicate a problem).
- Ensure water disinfestation is working properly and that disinfestation product is within range.
- Test other aspects of water quality.
- Analyse for nutrient levels in foliage (NPK plus trace elements), compare leaves of a similar age from symptomatic and asymptomatic plants if available.
- Test other equipment critical for successful plant growth, e.g. underbench heaters, seed storage parameters, etc.
- Irrigate optimally and ensure the correct moisture level and media air filled porosity. Low oxygen environments can cause root rot that may result in a variety of symptoms including those of a nutrient deficiency. Portable blue-tooth enabled tensiometers are available and are relatively inexpensive.

5. SYNTHESISE AND MAKE PLAUSIBLE, SIMPLE THEORIES

Examine the information available with an open mind, critically evaluate and list those factors that are most likely to have caused the symptoms. In general, those explanations that are simplest should be given precedence as being most likely to have caused the symptoms. Gauge if there is information surrounding the observed symptoms that is apparently inconsistent with each possible factor. If necessary, gather additional information or complete more tests to help resolve this process and assist in prioritising the most likely explanation. This may involve moving between steps 5 and 6 on many occasions.

6. TEST THEORIES WITH SMALL NURSERY TRIALS

Based on possible explanations, complete small test trials. When doing so it is critical that there is always a point of comparison. If the theory is that light intensity is the causal factor, then plants must be placed in multiple levels of light intensity (e.g. low, medium and/or high). This allows for inference and examination of how the level of light has changed plant growth. Try to keep all other factors relatively similar between the treatments. If you suspect a particular product is phytotoxic, apply the product to only a small portion of the crop, mark it and compare it with the area that did not receive it. This same concept can be applied when trialling new growing methods, e.g. fertilisers, growing media etc. Always have an untreated control as a point of comparison. A difference in growth provides evidence that your treatment has had an impact.

Dieback and deformed new growth caused by irrigation water with very high pH.

PART 2. COMMON SYMPTOMS OF ABIOTIC DISORDERS

NECROTIC MARGINS OR TIP BURN OF LEAVES

This symptom may be produced in plants with an internal water deficit or a variety of other factors. It can result from under or oversupply of water or damage to the roots (which effectively reduces the ability of the plant to take up water). Root damage may be caused by a pathogen, pest, nematode or other factors including high salt concentration (EC) in the growing medium, low oxygen in the growing media, high or low pH, nutrient toxicity, accidental herbicide application and even extremes in growing media temperature.

The need for good drainage and aeration in growing media is critical for plant growth. Within a few hours of water saturation microorganisms and roots use up most of the oxygen present; nitrogen, carbon dioxide, methane and hydrogen begin to accumulate, which restricts water uptake by the plant.

Salinity can affect plants in two ways:

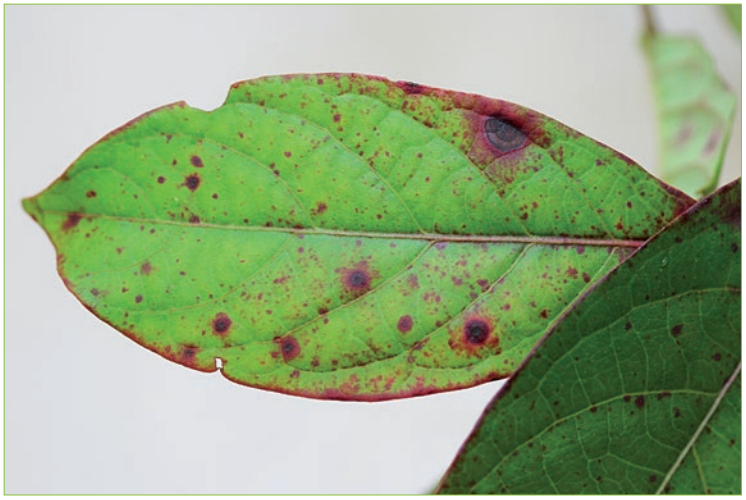
1) High salt concentrations (high electrical conductivity (EC) values in growing medium analysis) depress the water potential and thus restrict the uptake of the water.

2) Physiological disorders can be induced by toxicities of specific ions such as sodium, magnesium, chloride or borate.

In salt sensitive species, expanding leaves are affected by marginal necrosis that may spread to the entire leaf. Wilting and necrosis of shoot tips may also occur, followed by necrosis of older leaves. In salt tolerant species, the only symptom may be necrosis and early senescence of older leaves. If the growing medium is saline, leaching by water flushing is necessary. It is essential to determine whether salinity is due to applied fertilizer; growing media ingredients or high salts in irrigation water. If the nursery is near the ocean, wind-blown salt may cause leaf-tip necrosis and eventually affect the entire leaf.

PORTIONS OF THE LEAVE OR STEM TURNING RED, BLUE OR PURPLE → ANTHOCYANINS AND KINOS

Some plants respond to stress by the production of anthocyanins or kino (woody plants). Anthocyanins are water soluble pigments that may be red, purple or blue. Some of the colours of "autumn leaves" result from anthocyanin production, as does the new redish-purple growth of roses. The pigments in leaves can also be produced in response to invasion by leaf pathogens. Anthocyanins become very noticeable when unmasked by the break down of chlorophyll as a result of stress or senescence. Factors that can lead to anthocyanin production include accumulation of soluble carbohydrates, low temperature, high light intensity, water stress and other factors that are stressful for certain plant species.



Red regions resulting from anthocyanin production around necrotic leaf spots caused by anthracnose.

When the cambium is injured in woody plants, a dark red resin (kino) is produced, e.g. on stressed *Prunus* species. It is gelatinous when moist but soon hardens after exposure to air and sun. Kino production is a mechanism of resistance against fungal invasion and insect attack and can be induced by mechanical damage, fire, frost, sun scorch, or boron deficiency. Kino production is also a common symptom of a canker diseases.

RAISED OR SUNKEN NECROTIC SPOTS → OEDEMA, INTUMESCENCE, ENATION AND EDEMA

Oedema is the name given to a small area of water-soaked cells on the surface of leaves, petioles and stems, which usually develops into a dome shaped swelling known as an intumescence. When the outgrowths are from the veins they are called enations. These disorders are induced by high relative humidity, combined with excess water where water uptake exceeds the rate of loss from transpiration. They are swollen mesophyll cells which have undergone cell enlargement (hypertrophy) and rapid cell division (hyperplasia). In very humid weather the cells often burst giving the condition called edema, producing sunken necrotic regions. Sometimes other conditions can cause these symptoms when they cause plants to send more water to cells than can be transpired, for instance under certain light conditions.

These disorders can be reduced with good ventilation and by limiting water in cool, cloudy, humid weather when plant transpiration is reduced. Conditions that cause them vary with each species; some varieties can be more prone or resistant.

Symptoms consistent with oedema on leaves of *Dipladenia* (above) and edema on cauliflower (below). Spots are about 1mm in diameter.

CHILL INJURY → NECROTIC SPOTS, LEAF YELLOWING

Exposure of tropical and subtropical plants to temperatures below 10°C greatly reduces or even stops growth. When there is limited exposure to these temperatures cellular processes are reversible, but with greater exposure they are irreversible, and lead to cell death. Necrotic spots will appear on the leaves. Chill injury also results in the inhibition of photosynthetic activity with leaf yellowing (photooxidation of chlorophyll) occurring after extended exposure to low temperatures. The obvious cost to the nursery is the reduced conversion of intercepted light into plant dry matter, with little or no growth. Plants that are over-fertilized, especially with nitrogen, are more sensitive to chill damage than those fertilized correctly.

SUMMER SCORCH, SUNSCALD → NECROTIC MARGINS, BLEACHING

Summer scorch refers to the condition where the plant cannot physically transport sufficient water to leaf margins. This results in browning of the leaf margins.

Sunscald is where there is a bleaching or bronzing of exposed leaves. These symptoms appear quickly when plants are moved from a shaded area into direct sunlight. If young seedlings do not have sufficient foliage to protect their stems from high light intensity, a dark water-soaked, lesion may appear at the base of the stem. Affected plants will then develop a damping-off type symptom.

Seedlings should never be moved directly from a shaded area into direct sunlight. They should be moved gradually from low, to medium, to high light over a period of several weeks.

Burn on *Syzygium* caused by severe heat. New growth is healthy compared to older, burnt foliage.

PESTICIDE/CHEMICAL PHYTOTOXICITY → UNUSUAL NEW GROWTH

Agricultural chemicals can be phytotoxic particularly if applied at high rates or under adverse conditions. Plants growing rapidly under optimal conditions are more sensitive to pesticide application. With foliar application the young growth is more likely to show damage; when applied directly to the growing medium or through irrigation, the older leaves are generally the first to be affected. Pesticide damage may produce a range of symptoms including stunting, burn to leaf tip or margin, yellowing and distortion of young leaves and shoots, tissue around veins paler than the rest of the leaf or defoliation. When applying a new pesticide or a pesticide combination (with a wetting agent or another chemical) for the first time, it should be tested for phytotoxicity on a small batch of the plants.

Furthermore, various chemicals that occur in water at high levels can cause a similar reaction, e.g. chloramines. This may occur as a result of a dam inversion perhaps in combination with low water levels in the dam. High levels of other chemicals in water can also cause unusual growth. For more detailed information refer to the phytotoxicity webinar on this topic.

NUTRIENT DEFICIENCIES, EXTREMES OR IMBALANCES

Nutritional problems usually affect all the plants of the same species in a nursery crop. All leaves of similar physiological age will generally have similar symptoms.

If a nutritional disorder is suspected measure the pH and electrical conductivity (EC) of the growing medium; these factors can often interact with nutrient disorders. Also research if the observed symptoms match those that may be published or described online. It may also be valuable to send foliage for nutrient analysis; be sure to include trace elements. If possible, send both symptomatic and asymptomatic leaves of a similar age as a point of comparison.

'J' ROOT AND OTHER DISTORTED ROOT SYSTEMS

A 'J' root is produced when a tap root grows upwards. This will stress the plant and make it more susceptible to disease. For example passionfruit seedlings growing in nurseries are particularly susceptible to *Fusarium solani* root and crown rot when they have a 'J' root that may have resulted during transplanting.

If the growing container is too small, the plant will quickly become pot bound and can also cause distortion of the tap root.

Nutrient deficiency may result (despite adequate fertilisation) and may also cause plants to have increased risk of infection by soil borne pathogens.

Constricted and bent roots do not promote healthy plant growth.

AIR POLLUTANTS

Air pollutants such as sulphur dioxide, ozone, fluoride and acidic aerosols are likely to damage plants. This is rare in Australian nurseries.

STRESS FACTORS THAT PROMOTE DISEASE

It is generally accepted that when plants are stressed there are suboptimal rates of growth as well as increased susceptibility to plant pathogens. Endophytes belonging to the fungal family *Botryosphaeriaceae* have the ability to become aggressive plant pathogens when plants become stressed. Abiotic stresses include extreme weather conditions especially under or oversupply of water, mechanical damage, interplant competition or off-site planting.

The extent and progress of devastating diseases caused by *Phytophthora* species is also heavily influenced by weather conditions. On poorly drained sites, or after flooding rains, there is a progressive destruction of the fine feeder root system of trees. If such trees are then faced with drought conditions they will become stressed and suffer serious decline.

Pinus radiata planted too deeply and with very few roots above the distinct layer of fertiliser. This probably led to poor plant health and increased risk of infection by *Phytophthora cinnamomi* (which was also detected).

This document was prepared by Ken Pegg, Andrew Manners, Tony Cooke and Lindy Coates (Agri-science Queensland, Department of Agriculture and Fisheries, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) as part of the Hort. Innovation, levy funded project 'Building the resilience and on-farm biosecurity capacity of the Australian production nursery industry' in 2018. Thanks go to Roger Shivas (DAF) for reviewing this paper.