Issues Relating to the Properties of Potting Media©

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A number of key physical and chemical characteristics of potting media are identified and described along with descriptions of their relationship to each other. These characteristics are not independent — they interact. Techniques for measuring some of these characteristics are described and guidelines for the interpretation of results provided.

INTRODUCTION

The limited volume of growing media within a container needs to supply the plant with all of its requirements of water, air, and nutrients as well as anchorage and support. To do so a container medium needs to possess certain physical, chemical, and biological properties. Ensuring that the medium initially meets these criteria and, just as importantly, continues to meet them is one of the key functions of production management in the nursery industry.

Growers need to be able to both measure some of these key characteristics and then interpret what the measurements mean in terms of their crops and their production systems. These characteristics are not independent — they interact — and interpreting how they impact on each other is critical if we are to make maximum use of our growing media. This paper will review both the measurement and interpretation of some key physical and chemical characteristics of potting media. The biological properties will require a separate review at a further time.

PHYSICAL CHARACTERISTICS

A number of key characteristics can be identified: total porosity, air-filled porosity (AFP), bulk density, water-holding capacity, wettability, and shrinkage. **Total porosity** in an organic based potting medium may well be around 50%, or higher, but it is the nature of that pore pace which is most significant in its impact on media properties. A medium with a high proportion of large pores will hold little water and necessitate high frequencies of irrigation. This medium has a high **air-filled porosity** (AFP). Ideally a medium will have a blend of large and small pores so that it both drains freely but also retains a reasonable amount of water in the smaller pores and in a layer surrounding particles and held by adhesion forces. What is obvious is that both water-holding capacity and aeration depend, in large part, on the AFP of the medium. Increase one and you will decrease the other.

One of the "problems" when measuring the AFP is that the container itself will influence the result. This is particularly so in respect to the height of the pot, since the height of the saturated zone of medium at the base of the pot will be the same regardless of the height of the pot or its width. The AFP is also likely to change over time as particles break down. This will mean that the AFP will decline as the crop is growing. Finally, of course, plants vary in their AFP requirements.

There are several choices for growers when determining the AFP of their medium. Two alternatives are suggested. The first, and preferred choice, is to use the Australian Standard (AS 3743 – 1996 *Potting mixes*) technique and then use the interpretation supplied by Handreck and Black (1994) to decide if the AFP is appropriate for your proposed use. An alternative method was described in the December 1999 IPPS Australian Region newsletter and provides a means of measuring the AFP in the container that is to be used for the crop. This technique allows growers to make informed decisions about the suitability of a medium when planning production of a crop or changing some aspect of the production cycle, such as moving from a “standard” shape pot to a “squat” pot.

In many respects arriving at the optimum AFP is the critical physical characteristic to be obtained. Growers can manipulate the AFP, and other physical characteristics, in the initial design of the medium by varying the individual proportions of the various substrate materials. The materials we use in the “construction” of potting media contribute their own unique characteristics to the eventual medium. Arriving at the optimum physical characteristics for a medium is very much about arriving at the appropriate substrate components.

The bulk density is the mass, in grams, of a dried cm^3 of medium. Somewhere in the range of 0.3 to 0.6 $g\,cm^{-3}$ is the recommendation from Handreck and Black (1994). This will provide reasonable “ballast” for larger plants while having modest pot weight. Simply take a known volume of medium and place it in a paper bag. Dry it at $105^{o}C$ for 24 h. Weigh the sample and record its mass. The bulk density is the mass of the dry sample (g) divided by its volume (cm^3).

The **water-holding capacity** of a growing medium is clearly related to the AFP. By increasing the AFP we decrease the water-holding capacity of the medium and by decreasing the AFP we increase the water-holding capacity. In the first instance higher frequencies of irrigation will be required and, in the second, gas exchange will be impaired and waterlogging may result. A balance is required.

In addition to this balance between gas exchange and water-holding capacity it is worth making the distinction between water-holding capacity and the amount of water readily available to the plant. Water stress to plants can reduce growth rates well before any signs of wilting occur.

Handreck and Black (1994) make the point that “ ..if plants in containers are to grow vigorously, the medium around their roots should not dry beyond 10 kPa and for open mixes the limit should be 5 kPa (of suction or tension)”. A suction, or negative pressure, of 1500 kPa is required to remove water at permanent wilting point. Clearly if we want to maximise growth rates we should be keeping the medium at close to container capacity. When medium dries to near wilting point the organic components within the media are difficult to re-wet and can become hydrophobic. The medium may also shrink within the container. The use of a wetting agent can improve the **wettability** of the medium. The Australian Standard technique for the measurement of wettability is reported in Handreck and Black (1994).

CHEMICAL CHARACTERISTICS

A number of key chemical characteristics can be identified: media pH, electrical conductivity (EC), cation exchange capacity (CEC), and nutrient levels. These characteristics also interact with each other and with physical characteristics. The **pH** is the level of acidity (or alkalinity) of the medium. Its main significance is that it can influence the availability of nutrients to the plant.

The various techniques available for measuring pH are also reported in Handreck and Black (1994) and the authors make recommendations on the most appropriate levels of pH for various crops and on techniques for adjusting pH. Clearly plants vary in what will be an optimum level of pH but for the majority of container grown crops, in organic-based potting mixes, a range of 5.5 to 6.3 will be fine.

Salts, including fertiliser salts, consist of an anion, or negatively charged component, and a cation, or positively charged component. Plants utilise some of these charged ions as nutrients. For example, the fertiliser "salt" ammonium nitrate consists of the cation NH_4^+ (ammonium) and the anion NO_3^- (nitrate). The two components separate in the medium solution and are then available for uptake by the plant. Plants can only obtain their nitrogen (N) in the form of these ions. Alternatively these ions may become "attached" to an exchange site or they may be leached from the container or perhaps used by microflora in the medium.

The **cation exchange capacity (CEC)** of a medium is its ability to retain cations and exchange, or release them, into the medium solution where they are available for uptake by the plant. Growing media typically has a much greater capacity to retain cations than anions. This is significant since it means that nutrients in the form of anions are typically leached more readily than the cation nutrients.

How readily the medium solution transmits an electrical current, its **electrical conductivity (EC),** provides us with a guide to the salt concentration within the medium. The greater the level of salts the greater the EC. It is used extensively in nurseries to provide an indication of when to add supplementary fertilisers or, conversely, when to leach excess salts from the medium. Some interesting interactions can occur when interpreting EC measurements. Salt damage can occur even when EC measurements are low. If the medium is allowed to dry, or if the AFP is high and irrigation frequency is not high enough, then the salt present in the medium solution becomes concentrated, since the water will be used by the plant at a faster rate than the nutrients, and damage will result. This also means that an increased osmotic gradient will exist making it even more difficult for the plant to take up water.

Another cautionary note when using EC as an indicator of when to fertilise is that EC is a "non-discriminatory" measurement of the salts in the medium solution — it tells us little, or nothing, about the levels of individual nutrients. We know that plants will use some nutrients at faster rates than others and we also know that some salt components are more "mobile" than others. There is much less capacity for retention of the anion components of fertiliser salts, such as nitrate (NO_3^-), within the medium. These are generally leached at a faster rate than the cations, such as the ammonium (NH_4^+) cation. Not only will anions be generally more mobile, and therefore lost from the container more readily than cations, but some of the cation components will be more "tenacious" on the cation exchange sites and therefore more able to resist leaching, than others. The degree of "tenacity" on exchange sites is largely, but not entirely, related to the valency or number of charges carried by the ion. A practical consideration of this is that by basing supplementary fertiliser applications on the use of EC we may be creating hidden toxicity levels of the nutrient ions more resistant to leaching while not supplying an adequate amount of the more mobile nutrients.

A good **nutrition** program will supply the plant with the optimum level of nutrients in the correct balance with each other. An excess of one nutrient may cause an “induced” deficiency of another. This can be an issue when we ignore the nutrient status of the raw components of potting medium and simply supply the “complete” package of nutrients in the added fertiliser. We know that pine bark, for example, will supply a significant amount of potassium (K) so when we add the “complete” package of fertiliser is the result too much K? If so could this lead to an induced deficiency of another nutrient?

The best way to determine if the immediately available nutrient levels are in the optimum range or not, and in the correct proportion to each other, is to measure the individual nutrients in the medium solution rather than the total package of salts in the form of an EC measurement. A number of systems are now available for measuring, with varying degrees of accuracy, nutrient levels from media solutions. However before we can be confident in their use we need to calibrate these methods against the Australian Standard technique that is used by laboratories when measuring nutrient levels in media.

CONCLUSION

Medium characteristics interact with each other and growers need to be aware that even “minor” changes to their production systems, such as changing pot designs, can influence key characteristics and impact on productivity. Growers need to be able to both measure key characteristics and interpret the results. As these characteristics will change during the period that the crop is being produced, regular assessment of the medium is desirable.

LITERATURE CITED

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