Soilless mixes — what's important and why?

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As the use of soilless growing media continues to increase, this article is designed to provide an understanding of some of the key terms, and to provide insights into the considerations required when thinking about soilless mixes as a growing media option. This article is intended for general knowledge building and is not designed to be referenced to recommend the use of any one growing media over another.

KEY TERMS EXPLAINED

Physical characteristics

Air-filled porosity (AFP)

The amount of air in a mix. At least 10-30% of the volume of the mix should be filled with air. AFP is calculated immediately after the mix has been saturated with water and allowed to drain and it varies with the size and shape of the container. Filled with the same volume of mix, a wider, shallow container will have a lower AFP than a tall, narrow container. AFP will decrease over the life of a potting mix as its components degrade.

Water holding capacity (WHC)

The ideal mix will retain enough water to prevent the plant becoming stressed at the chosen irrigation frequency. Generally, one to two thirds of the volume of the mix should be available for water. It must not hold too much water as that will reduce the AFP. Like the AFP, the WHC is influenced by the shape of the container – for the same volume of mix, a shallow container will retain more water than a slimmer, deeper container (Figure 1).

Bulk density

A measure of the weight of a mix for a given volume. A litre of sand is heavier than a litre of peat or pine bark. Bulk density is a function of the density of the particles in the mix and the porosity of the mix. It is a consideration in situations where manual handling of containers is required and where containers may be exposed to wind.

Shrinkage

When designing a potting mix, it is important to consider the length of the crop cycle. Shrinking of the mix can result in plants becoming unsteady. AFP will decrease and nutrient and moisture storage will change. Larger particles are generally more stable. Sawdusts shrink faster than barks. Media high in organic matter can also shrink due to the activity of microbes, earthworms and insects.

Sand and soil do not shrink but will migrate within the container and cause problems. Perlite, polystyrene, scoria and coarse barks and coir are all relatively stable.

Wettability

The ease with which mixes can be moistened. Many types of organic materials are initially hard to wet and even more difficult to re-wet after they have dried out.

Hydraulic conductivity

A measure of how easily water moves throughout a mix. It is a function of the mix component(s) and the moisture content of the mix (but is not a constant relationship) and can be shown as a graph. Hydraulic conductivity is often quoted as 'saturated hydraulic conductivity' which is only one point on the curve – that at which the mix is saturated (at field capacity). Coarse mixes will have a lower hydraulic conductivity than fine mixes. Coir has a low saturated hydraulic conductivity —about one-sixth of that of perlite.

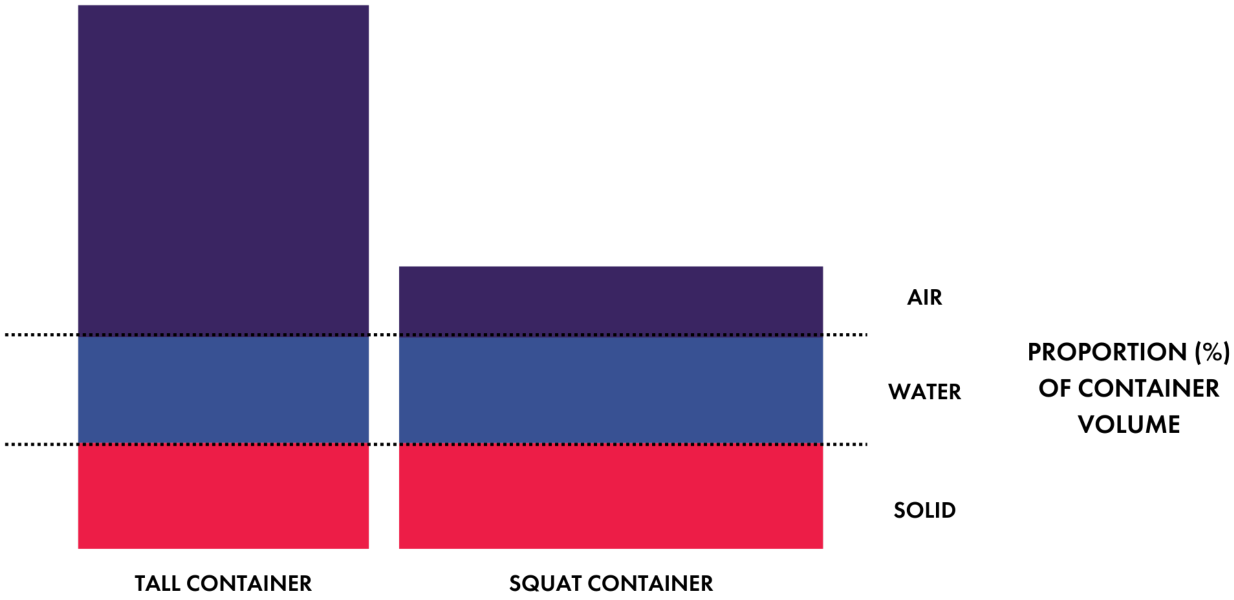

Figure 1. Water holding capacity.

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Chemical characteristics

pH

The concentration of hydrogen ions in the mix. Seven being neutral, anything lower is acidic and above 7 is alkaline. The availability of nutrients in a potting mix is determined by pH but the relationship is not the same as for soils. pH is seldom constant and can change depending on the composition of the irrigation water and the types of fertiliser used.

Cation exchange capacity (CEC)

A measure of the amount of nutrient (cations i.e. positively charged particles) that can be held by the mix components. Sand and perlite have the lowest CEC, clay minerals and organic matter, the highest. The term exchangeable cation is used because it is the movement of these cations within the mix that drives plant nutrition.

Electrical conductivity (EC)

Water containing dissolved ions (including plant nutrients and sodium), conducts electricity. The higher the concentration of ions, the greater the amount of electricity conducted. Ion concentration is measured with a conductivity meter but for readings to be meaningful, the correct methodology must be used. Methods for soils are different to those used for potting mixes.

Soilless media in crop production

Potting mixes have changed considerably over the years. Initially, they were closely allied to soil (but in a container) with most nutrients added to the mix at the beginning, for the life of the plant, but with the addition of side dressings of animal manures. Now mixes are largely inert from a nutritional point of view, with the emphasis on supplying the desired physical characteristics in terms of water holding capacity and aeration. The nutritional component is now supplied largely via the irrigation water in a closely monitored and regulated fashion using equipment that continuously measures and reports on the nutritional (usually in terms of EC) and moisture status of the crop.

In the early 1980's the use of soil in potting mixes was still accepted. John Innes composts were still used. These originated in the 1930's at the John Innes Horticultural Institute at Merton, Surrey in the UK. Loam is the crucial ingredient but is in increasingly short supply and regarded as unsustainable. Modern John Innes media contain soil ingredients that are not necessarily loam, such as peat. They are easy to manage as the soil has a high level of buffering - avoiding fluctuating water and nutrient content.

My first research project in 1983 was looking at the use of pine bark media for potting mixes to replace peat which was increasingly regarded as also becoming unsustainable. In Australia there are two main species of *Pinus* used in potting mixes- *P. radiata* and *P. pinaster*. In other countries other softwood species are used for bark such as Douglas Fir. Certainly, in Western Australia, pine bark is becoming more difficult to source.

In recent years, coir has become increasingly popular. But even now the same questions are emerging: ***should we be clearing land with existing forests to plant coconut palms for coir?***

As potting mixes require large volumes of their components and some of those may also be heavy, it is logical that materials should be sourced as close to the point of use, as possible. Therefore, potting mixes tend to vary depending on location and tend to use local materials. Those materials may be mined locally - such as peat or pumice - or they may be by-products or waste products from other industries. I have often heard the comment '*horticulture should not be the dumping ground for the waste products of other industries*'! Of course, the truth of this comment probably rests on the actual value of the material and before any new potting mix component is used it should be evaluated in terms of its chemical composition (including possible contaminants and variation between/across sources), physical characteristics, longevity and potential interaction with other potting mix components.

The obvious disadvantage in using soil in a potting mix is that soil is not one entity. Its chemical and physical characteristics vary depending on the proportions of sand, silt, clay and organic matter. Clay alone varies hugely in its characteristics depending on the type of clay mineral (s) and its lattice structure. Getting uniformity and repeatability in a product grown in such mixes is difficult.

Potential materials for use in soilless mixes

Peat (sphagnum peat in particular) has been the mainstay of soilless mixes for many years. The extensive use of peat is due to relatively low costs in these areas, its excellent chemical, biological, and physical properties with low nutrient content, low pH, a unique combination of high water-holding capacity by high air space and drainage characteristics, light weight, and freedom from pests and diseases. The unique properties of sphagnum peat and its resistance to degradation are matched by few other growing medium constituents. The leading peat-production countries are Finland, Ireland, Germany, Sweden, Belarus, Canada, and Russia, which account for 80% of the world's production. However, peat is a limited resource with a great demand, and the extraction of peat bogs causes negative impacts on the environment.

Other organic materials may play an important role in decreasing the carbon footprint of the horticultural industry by fully or partly replacing peat-based substrates. Compost, coir, bark, and wood fibre are some organic materials that are already being used in a commercial way as an alternative to peat. In addition, some inorganic materials, such as vermiculite, perlite, clay granules, lava, and pumice are used mixed with peat, while new organic materials, such as sphagnum moss, waste and digestates, biochars, and hydrochars are still in their test phase.

Soilless substrate components

Bark

Bark is a major component of growing media, particularly in areas where peat is scarce or expensive, due to transportation cost. It is a lightweight material with a bulk density of 0.1–0.3 g cm^3. Like coir, bark can be produced in different particle sizes, which makes adjusting the air and water-holding capacities possible by varying the percentage of fine particles. Pine bark is not produced specifically for use in growing media and tends to have variable physical, chemical, and biological properties. It is usually used as a composted or aged material, in order to avoid potential problems with phytotoxicity, since the presence of phenolic compounds, terpenes, and tannins are typical in the chemical composition. High manganese content in some barks can be a source of potential phytotoxicity. Nitrogen drawdown is a common issue if the bark is used without being composted prior to use.

Wood products

Wood fibre, wood chips, and sawdust are renewable resources from the forestry sector. All these products are characterised by low water retention and good air content. Depending on the initial material, they can contain phytotoxins that may affect the plant growth at the beginning of cultivation. In this case, a pre-treatment with substrate washing would be recommended. Particle-size distribution determines further physical properties, e.g., water retention and water-holding capacity. A very good correlation was detected between the high percentage of particles <1 mm and max. water holding capacity, and therefore plant growth. Cation exchange capacity is lower than that of pine bark.

Wood fibres are further used to optimise the physical properties of other material components, e.g., reducing bulk density, increasing air space, improving re-wetting capacity and/or as an organic mulch to reduce soil temperature fluctuations, and soil water evaporation and suppress weeds. The longevity of woodchips and sawdust is highly dependent on particle size.

Coir

Coir is the material that forms the middle layers or mesocarp of coconut fruits. Coir pith, coir fibres, and coir chips are some of the most abundant plant-derived organic waste materials in many tropical and subtropical countries and has been notable as a rapidly renewable resource. The use of coir in growing media has vastly increased since 2004, particularly in Europe and the United States, and concerns about its sustainability are growing. Coir pith has the highest impact on "ecosystem quality", which is often due to land occupation during the coconut harvesting stage.

Like peat, coir is used in mixtures for the potting industry as it is a lightweight material and has good air and water holding characteristics.

Since coir contains more lignin and less cellulose than peat, it is more resistant to microbial breakdown and usually shrinks less; it is easier to re-wet after drying than peat moss and tends to retain its basic structure when wet or dry.

In general, horticultural coir does not contain a lot of large pores, and that is why it is commonly mixed with aggregated mineral substrates to enhance its aeration properties.

Coir has the highest amount of ammonium absorption due to its high cation exchange capacity (CEC). Leaching of nitrogen is marginally higher than for peat and the total water-holding capacity is lower (for materials of a similar particle size).

Because of differences in industrial source and pretreatment of coconut coir, considerable variations in physicochemical and hydraulic properties can be expected. This can include higher total soluble salts, sodium, and chloride levels.

Coir is the material that forms the middle layers or mesocarp of coconut fruit. Photo credit: Shutterstock

Perlite

Perlite is a glassy volcanic rock produced by heating the raw material (once ground and sieved) to 760-1100°C. It is very light having a bulk density after processing of 30-150 kg/m^3. It is produced in a range of grades. It can hold three to four times its own weight in water but that is highly dependent on particle size. With coarser grades, much of that water may be held internally and unavailable to the plant. Finer grades of perlite demonstrate very high levels of plant water availability.

Perlite is neutral with a pH of 7.0–7.5, but has no buffering capacity and contains no nutrients. It exhibits favourable nutrient adsorption characteristics. Despite the high affinity of phosphorus to perlite, the importance of P adsorption is small due to a low maximum adsorption capacity and the low bulk density of perlite. Ammonium adsorption to perlite is also negligible. Perlite can be disinfested and re-used. It has been shown to be stable over up to 8 years.

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