Soilless mixes – what's important and why?

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- The ability to monitor substrate nutritional and moisture status in almost real time is challenging traditional substrate theory.
- Reliance on the physical characterisation of mixes has assumed irrigation and fertigation schedules that are largely obsolete in today's modern substrate production.

In the previous article we explored the key characteristics of substrates and why they are relevant to soilless production. Now we are going to take a deeper dive into what happens when you start changing things in a mix and highlight some of the research that is going on around the world into soilless mixes.

Things to consider when changing a soilless mix

Nothing happens in isolation. If you want to change your mix, or even one component of your mix it is a big step. Each mix component has its own properties, but when combined with other mix components there will be interactions to consider:

- **Physical:** structure stability, gradation, internal pores, retention curves (water buffer, Easily Available Water) and WOK (water uptake characteristic).
- **Chemical:** initial pH, buffering (pH, cations), nutrient load, nitrogen drawdown and biological aspects.

For each raw material in a mixture, the effect and interaction with other raw materials must be evaluated.

In addition to the basic chemical and physical properties there are other considerations:

- Could the raw material be carrying pests, diseases or weeds and therefore does it require a treatment such as composting or steaming/pasteurisation?
- Could it be carrying other chemicals or residues that may be harmful to the crop? Herbicide and antibiotic/pesticide residues, for example, have been found in composts.
- Could it contain other contaminants such as glass, plastic or stones? Plastics may even contain other substances such as dyes that can be harmful to plants.
- Could it have high levels of other undesirable ingredients like heavy metals? Certain barks can be high in manganese, for example.

What testing has been carried out?

If you are being offered a product or mix component, it is important to ask what testing has been done and were the tests relevant for the material? Tests for wood based mixes are not the same as those for soil. It is also important to note that not all laboratories are accredited for testing soilless mixes. ASPAC certification only ensures that labs get similar results for the same test. NATA certification ensures that the correct test is being performed. There is an Australian standard for potting mixes (AS 3743—2003) but it is not really relevant for soilless substrate mixes such as coir-based mixes. It is a different scenario in Europe where there is a privately operated scheme for substrate mixes. The RHP quality mark monitors the quality of growing media in the supply chain, from raw materials production until processing and delivery to the end user. You can find out more about the RHP scheme at: www.rhp.nl/en/about-rhp

LEVEL OF AMMONIUM ADSORPTION				
More ←				→ Less
Perlite	Tuff	Tuff-coir mix	Perlite-coir mix	Growstone-coir mix

Tuff is a relatively soft, porous rock that is usually formed by the compaction and cementation of volcanic ash or dust. Tuff substrate derived from pyroclastic volcanic material is characterised by high porosity and surface area. Volcanic tuff is a reliable substrate for soilless systems.

Growstone® is a manufactured growing medium that is made from 100% recycled glass. Growstones' highly porous and uneven shaped aggregates provide a balanced combination of small pores inside each aggregate and large pore spaces between aggregates. This determines Growstones capacity to store water, air, and the ability to provide these to the plants.

Longevity of mix components

The longevity of a mix is a product of the interaction between its components. While materials such as perlite are almost inert, the impact of other mix components degrading can have an adverse overall affect.

For example, when pine bark degrades, the fine particles released can adhere to other materials in the mix and they will also move down and out in the profile and silt up around the edges and base. The air-filled porosity and water holding capacity of the mix will alter throughout the profile, especially near the base of the pot. Many commercial bark-based mixes only last 6-12 months. Long enough for nursery crops, but not nearly long enough for a perennial blueberry crop.

Mixes comprising composts and bark, or wood-based products are quite dynamic, especially if the wood materials are fine and pH drift may occur over time.

Coir mixes

The high level of ammonium adsorption in pure coir translates to mixes containing coir. But it should be noted that when substrates are mixed, the dry mass ratio is crucial for estimation of adsorption properties of the resulting mixtures. For example, 30% coir in a volcanic tuff-coir mix does not significantly increase ammonium adsorption because volcanic tuff is comparatively heavy.

In contrast, the 50% coir in a perlite-coir mixture significantly impacts ammonium adsorption due to an almost 30 times lower dry mass ratio than that of the volcanic tuff-coir mixture (coir and perlite are much closer in terms of their bulk density).

The order of affinities of ammonium to the substrates is greatest for perlite. Followed in order by tuff, tuff/coir, perlite/coir, coir and lastly Growstone®/coir. As expected, the k values for ammonium in the two component mixtures fall in between the values of the pure components.

Hydraulic interactions between perlite and coir

The addition of perlite to coir enhances aeration, allowing air to enter the mix more freely as compared to a mix of 100% coir. The addition of coir to perlite lowers saturated hydraulic conductivity, slowing down drainage and increasing the plant available water. The amount of water that can be extracted (after drainage) from pure coir, pure perlite and a 50:50 mixture of both is shown in Table 1.

Plant water availability (accessibility) of perlite is one of the highest of all substrates, followed by perlite/coir mixtures as shown in Table 2.

Note the large drop in easily available water as the perlite is increased to 50% in a coir/perlite mix.

Table 1. Amount of water that can be extracted from coir, perlite and a coir/perlite mix.

MIX	R VALUE*
Coir 100%	3.57
Perlite 100%	4.35
Coir/perlite (50:50 vv)	3.83

* R indicates the amount of water that can be extracted via exertion of a unit amount of energy by plant roots within the range of the wet-and dry-end thresholds. The higher R, the easier it is for plants to extract water.

Table 2. Physical properties of pure coir, and two coir/perlite mixes.

SUBSTRATE	TOTAL POROSITY %	AIRSPACE % AT -10 CM	EASILY AVAILABLE WATER %	WATER BUFFERING CAPACITY	DIFFICULT AVAILABLE WATER %	UNAVAILABLE WATER %
Suction Pressure Head (cm)		-10	-10 to -50	-50 to -100	-100 to -1500	> -1500
Coir 100%	91.50	20.07	32.09	7.85	18.49	13.00
Coir: perlite 75 : 25	88.50	20.92	30.88	6.64	17.06	13.00
Coir: perlite 50 : 50	72.00	23.00	22.00	6.30	8.70	12.00

Source: Adapted from Table 4 Londra Paraskevi, Angeliki Paraskevopoulou and Maria Psychogiou, 2018

In the past, characterising the physical parameters of mixes and their components has been of utmost importance. However, these physical parameters are static and should be used only as references, because the only criterion for defining them is negative water pressure head. The important role of the dynamic hydraulic properties of the substrates such as gas diffusivity, hydraulic conductivities over the range of moisture contents, their chemical composition, and the growth peculiarities of different plants was not previously considered.

During plant growth in pots or in the field, a dynamic state is formed that constantly changes over time and space. Therefore, the method, timing, and amount of irrigation water beyond the values of the physical properties of the previously "ideal substrates" plays a significant role in defining a substrate as "ideal" or not.

A summary of current substrate research

Wood based products

North Carolina State University is focussing largely on the engineering, characterisation and utilisation of wood-based substrate components. Recent trials have been evaluating commercially available wood products from both North America and Europe. However, the longevity of wood-based materials is highly dependent on particle size and probably of more value to the nursery industry where production timelines are shorter (that is less than one year).

Read more at:
woodsubstrates.cals.ncsu.edu/publications

Stratified substrates

Stratified substrates, or layering growing media within a container, is a recent innovation being led by Dr. Jeb Fields with the LSU AgCenter and Dr. Jim Owen with USDA-ARS. The concept was initially designed to improve water management by altering the physical nature of the container.

Layering substrates with high water-holding capacity on top of coarse materials to promote drainage allows re-engineering of the water distribution within the substrate system. It permits increased water holding in the upper portion of the container and reduces water holding in the lower—a reversal of a typical container system. This creates a more uniform moisture profile throughout the substrate and allows for improved water resource management, in addition to supporting improved root growth.

Stratified substrates also have the potential to lower media costs by stacking high-cost substrates on top of low-cost substrates. For example, utilising a low-cost pine bark substrate on the lower portion in high-performance, peat-based media may cut media costs with additional potential benefits.

Coir

Researchers at NC State and the University of Arkansas (Dr. Ryan Dickson) are conducting an evaluation of coconut products (fibre, chips, coir, etc.) with the goal of supporting the global manufacturers, suppliers and distributors of these substrate materials that are, and will remain, in extremely high demand.

The intention is to work with industry to further improve or advance processing and preconditioning methods and help to develop novel mixes and product formulations.

Biological properties

Research at the USDA-ARS Application Technology Research Unit and The Ohio State University (OSU) is looking at the biological properties of soilless substrates using Next-Gen (NG) amplicon sequencing techniques on soilless substrate DNA to determine the impact of substrate management practices on the microbial community.

Previously scientists have studied the bacteria and fungi in soilless substrates by observing the growth or suppression of one organism (beneficial or pathogenic) at a time. Using the NG amplicon sequencing approach, the entire community of fungi and bacteria living within the substrate can be identified.

The first goal of the project is to document the breadth of the community and how it changes over time under different management strategies. Substrate components such as pine bark, peat and compost affect the makeup and diversity of the microbial community early on. However, over time, the communities tend to become more similar regardless of substrate components, as the environment (temperature, irrigation water, etc.) has more influence on the community than the original substrate.

Longevity

As more perennial crops such as blueberries, are shifting to soilless cultivation systems, the need for longer-term substrate stability has to be addressed. Some of these crops will spend five to eight years or more in containers so the substrates used need to be resilient enough to provide the physical, chemical and biological stability needed to optimise yield and productivity throughout their production life. This work is being led by Dr. Gerardo Nunez at the University of Florida.

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