

SOILLESS SUBSTRATES

INTRODUCTION

Soilless substrates are used across the world, offering a solution to those with difficult soils to grow on, or those who are looking to increase production efficiencies. These substrates are comprised of non-soil components, but still provide the structural support needed to grow.

Here are some of the reasons for growing in soilless substrates:

- Mitigate accumulating disease pressure in soil caused by over-wintering pathogens
- Eliminates need for expensive soil disinfection between crop cycles
- Increased demand for local, year-round produce
- Intensive and repetitive farming in the same soil can become increasingly difficult over time
 - » Accumulation of salts, depletion of key nutrients, drainage issues, compaction
- Depending on the target crop, you can establish a more ergonomic setup by raising the crop off the ground
 - » Significant savings in labour
 - » Examples of this include greens, strawberries, cannabis, tomatoes
- Help mitigate weed pressure

- Complete control over nutrient and water delivery
- Improved resource management
 - » Less water and fertilizer are required per kg produce compared to a soil-based system
 - » Opportunity to collect and re-use fertilizer and water inputs

WHAT ARE SOILLESS SUBSTRATES MADE OF?

When it comes to the base material used for soilless growing media, there are a handful of options. These options are divided into two groups: synthetic and non-synthetic products.

Synthetic products have been manufactured to facilitate plant growth. As a result, these substrates are highly uniform in terms of particle size distribution. There should be no inconsistencies across grow bags or orders placed over time. Due to the nature of synthetic substrates, there is a lot of diversity in the products that are available for purchase. Across seed plugs, for example, there are opportunities for specific sizes, shapes, seeding depths, seed slots, and the types of carrier trays that they come in. For some setups, seed plugs will be sufficient for the duration of the cropping cycle (ex. Hydroponic lettuce production, microgreens etc). For longer production cycles of crops that require more structural support, these seed plugs can be transplanted into blocks, and then onto grow bags once the seedlings have established. One of the most common synthetic substrates is rockwool.



Figure 1. An example of the versatility of synthetic growing media. The size, shape, planting hole, and planting setup can be customized to maximize efficiency and plant production based on the production setup. Photo credit: Talia Plaskett.



Figure 2. A side-by-side representation of the versatility in planting systems when growing in rockwool. On the left, a rockwool plug is being planted directly into a trough, which will house the plant until it is time to harvest. On the right, a rockwool plug has been planted into a rockwool block, and then a rockwool slab. This setup is a necessity when growing year-round vine crops such as tomatoes, cucumbers, and eggplants, as they require significantly more structural support compared to a shorter cropping cycle. Photo credit: Talia Plaskett.

Non-synthetic substrates are natural materials that have been harvested and processed for use in plant production. Because these substrates are composed from living materials and have undergone limited processing, there is variation when it comes to particle size within a single grow bag or bulk order.

Non-synthetic growing media can be purchased in a few different ways. Bales of loose substrate can be purchased and delivered, and it is up to the producer to hydrate the substrate, pack into the growing containers and distribute through the grow space. This is ideal for crops that can be grown in containers throughout the cropping year, like brambles, cannabis, and strawberries.



Figure 3. An example of a container used for strawberry production that was manually filled with a hydrated substrate. Photo credit: Talia Plaskett

There is also the option to purchase grow bags that are pre-filled with non-synthetic substrate, similar to the system used for synthetic substrates. These bags need to be hydrated before use but are easier to distribute throughout the greenhouse for planting compared to a bale of loose substrate. This is commonly seen in the production of greenhouse vine crops (tomatoes, peppers, cucumbers, eggplants) but can be used for others as well (i.e. strawberries).



Figure 4: An example of a grow bag used for plant production. These bags can come with the option to customize slab size, depending on the supplier and the order size. Choosing pre-cut or uncut slabs, varying lengths, heights, and widths of the grow bags, as well as with or without drainage holes along the bottom of the slabs are some of the options available. Photo credit: Talia Plaskett

HOW DO SUBSTRATES MEASURE UP?

There are a handful of soilless substrates available on the market for purchase. Here is a look at how some of the most popular growing media compare:

	Rockwool	Peat Moss	Coconut Coir	Pine bark	Wood fibre
Density	0.08 - 0.09 g/cm ³	0.1 - 0.15g/cm ³	0.07 - 0.09 g/cm ³	0.12 - 0.18 g/cm ³	0.07 - 1 g/cm ³
Porosity	95%	70 - 80%	80 - 90%	65 - 75%	80 - 90%
Particle Size		0 - 25 mm	0 - 5 mm Mostly in the 0.5 - 1 mm range	0 - 16mm	0 - 10mm
Initial pH	7	5.5 - 6	6.5 - 7	4.0 - 5.0	5.3 - 6.3
CEC	0 meq/L	60 - 80 meq/L 40-80 meq/100g	40 - 100 meq/100g 40-100 meq/100g	30 - 90 meq/L 17-75 meq/100g	20 - 30 meq/100g 20-30 meq/100g
Post-harvest Treatment Options		Milling	Washing Buffering	Milling	Milling
Additional Notes	Variable when it comes to fibre orientation (vertical versus horizontal), diameter, size and shape	Large percentage of this substrate tends to have small particle sizes, which will decrease overall porosity	Option to request fibers, and chips of different sizes to offset a media that is otherwise skewing towards small particle sizes		Better for short term use versus long term growing: typically breaks down faster than bark or coir

These values are based on averages listed in the literature, and might vary depending on the substrate supplier.

Density

Bulk density is an indication of soil compaction which influences soil porosity, available water, and nutrient availability to the root system. A high-density reading is associated with low porosity and compaction, whereas low density readings translate to a high degree of porosity in the grow media and a low degree of compaction.

Porosity

This is a measurement of space within the substrate mix that is available to be occupied by water or air. Soilless substrates have a high capacity for holding water and air, which makes them well suited for plant production. Individual substrate particles do not tend to aggregate and will remain loosely packed as long as they are properly managed throughout the cropping cycle.

Particle Size

Substrates are classified according to particle diameter. Soilless substrate particles are generally larger, and much more porous compared to the particles that make up soil.

Regardless of the base material, typical grow mixes for substrate-grown crops contain of a range of particle sizes. Large particles are beneficial for creating and maintaining the vital air spaces in the mix, as well as encourage the drainage of water away from the root system. However, it is important to have some degree of water retention to reduce the number of irrigation events necessary to maintain the crop throughout the day. Fine particles in a substrate mix are very good at holding onto moisture, but do not allow for the creation of vital air spaces in the mix. The best substrate mixes are going to consist of a mix of small, medium and large sized particles to strike the perfect balance between water retention,

drainage, and air porosity. Substrate providers typically have a range of pre-mixed products that are balanced and functional in terms of particle size, but there is also the option to create custom mixes.

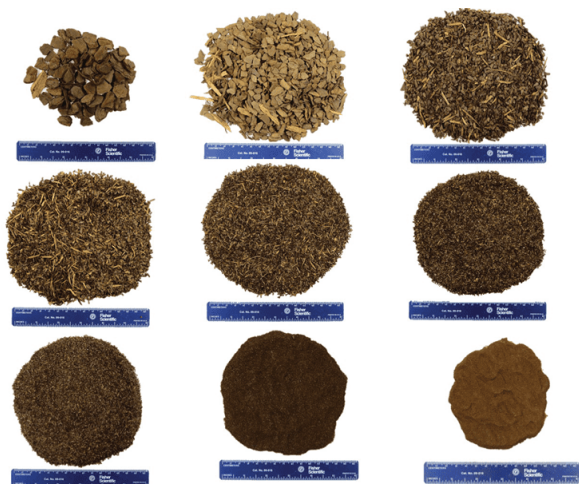


Figure 5. An example of the diversity of particle sizes that can exist within a substrate medium. This image depicts the variation possible for bark media, which can be easily engineered to accommodate these different particles. Photo credit to Greenhouse Management Magazine; Brian Jackson.

Starting pH

The starting pH is an indication of nutrient availability within the media before fertilizer solution has been introduced into the mix. This should be considered when formulating fertilizer recipes to account for excess acidity/alkalinity in the grow media which will skew your target pH without appropriate intervention.

CEC (Cation Exchange Capacity)

Cation exchange capacity refers to the ability of a negatively charged substrate particle to absorb positive ions, or cations, that are floating around within the growing container. These positive ions (Ca^{2+} , K^+ , H^+ , Na^+ , Mg^{2+}) are going to play a role in the nutritional status within the substrate.

A substrate's CEC value impacts EC management through the cropping cycle. Growing media with higher CEC values ($>100\text{meq/l}$), are going to be more resistant to fluctuations in EC compared to a media with a low CEC value. In a situation where the EC of a growing media is too high, a producer will flush the container to attempt to lower the overall EC

within the pot. Substrates with a high CEC value respond by releasing some of the cations that are held on the surface into the growing matrix, causing the reading on the EC meter to remain slightly, or completely, unchanged. Multiple flushes are required to lower the substrate EC into the desired range. A substrate with a low EC value is more responsive to system flushes, and will quickly release ions that are held on the surface. This translates to a higher degree of control over the growing environment, as little time is required to alter the root zone environment, but it can leave the producer vulnerable when it comes to un-checked issues with irrigation water and fertilizer solution.

Post-harvest Treatment Options

Once the soilless substrate has undergone initial processing to become a growing medium, it can be further modified to make it more suitable to support plant growth. The base material of the growing media is going to dictate which of these processes are necessary.

Milling — Milling is a strategy used to shift the balance of particle sizes in a growing mixture. Some materials are prone to a skew in their particle size towards the small end of the spectrum as a result of the harvesting process. Milling removes fine particles and dust from the substrate to create a more balanced ratio of particle sizes. The result is a suitable grow mixture that is able to retain water, facilitates easy water uptake by the plants, and maintains air spaces around the root system. By purchasing a product that has been milled, the majority of the finer particles, or dust, is removed from the mix. This will create a more suitable grow media to sustain a healthy root system through the crop cycle.

Washing — Coconut coir typically contains high background levels of Sodium (Na^+) and Chloride (Cl^-), while Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) are quite low. This is problematic for plant production, especially on young, newly transplanted plants. In order to deal with these background nutrient levels, the coir should be washed with clean water. This will pull most of the Na^+ and Cl^- ions out of the grow media and allow for a more balanced root environment. Unwashed coir can also cause significant staining to the facility and growing hardware (benches/troughs, floors etc), and is very difficult to remove after the fact. While washing can be done on farm, it is recommended to purchase a washed coir directly from the supplier.

Buffering — In addition to the high background levels of Na^+ and Cl^- , coconut coir has high baseline levels of Potassium (K^+) as well. Washing with water is not going to be sufficient to remove excess K^+ from the growing media, so a buffering step is necessary to create a more balanced baseline. This process allows for the replacement of K^+ ions with Ca^{2+} , which is a crucial element for plant growth. Buffering can be achieved through the application of soluble calcium sources like gypsum, lime, calcium chloride and calcium nitrate (most common). Similar to washing, coir can be buffered on site, but is ideally done by the supplier to ensure the process has been carried out fully. Failure to properly buffer the substrate before planting a crop leaves the producer highly susceptible to tip burn and poor plant performance that cannot be remedied through drip application of calcium. Running a high calcium feed in non-buffered substrate will displace the Na^+ and K^+ ions from the particle surface to the root zone, resulting in damage to the crop.

Substrate Lifetime

For most substrate-based crops (i.e., tomatoes, cucumbers, brambles), the substrate should only be used for one season and then discarded. For crops that have longer cycles, for example strawberries, it is important to consider how these substrates will degrade over time. Through the wear and tear associated with use, larger substrate particles are prone to breaking down into smaller particles. As the balance between the particle distribution begins to skew towards smaller particles, you are going to see a higher degree of moisture retention with slower drainage through the mixture. The producer must be aware that this is happening in the grow mix and adjust the irrigation strategy accordingly to minimize the impact on root health.



Figure 6. An example of a system where the plants, and the growing substrate, are kept for more than one growing season. This setup sees the continued use of a substrate for two years to maximize the output potential of these strawberry plants. Producers will have to keep the moisture retention capacity of this substrate in mind as it slowly breaks down over time and adjust the irrigation schedule accordingly. Photo credit: Talia Plaskett

In addition to the degradation of the substrate particles, there is always a risk that pathogens, salts, and weeds will accumulate in the growing mix from use to use. Whether it is a one-year crop or a three-year crop, it is always recommended to start your next cycle with clean substrate to maximize crop health and performance.

CONCLUDING REMARKS

While the switch from a soil-based system to a soilless substrate system might be daunting, it can open doors to maximizing year-round production. Containerized systems have been showed to be highly efficient in regards to water and fertilizer inputs, and even allows for the collection and re-use of irrigation solution. There is significant opportunity to reduce weed, pest, and disease pressure, as well as reduce labour cost.

For more information on growing in substrate, check out Perennia's follow-up fact sheet which focuses on necessary management changes when transitioning from soil to substrate. There are a handful of other resources worth exploring on the topic, including Perennia's 'Getting Into the Weeds' Webinars which are currently available on our Youtube channel:

- 2020-2021 'Getting Into the Weeds' session 'Making the Switch to Soilless Substrate'
- 2020-2021 'Getting Into the Weeds' session 'Irrigating my Soilless Substrate'

Stay tuned to Perennia's blogs for information on upcoming workshops, webinars, or fact sheets. If you have any questions on growing in substrate, don't hesitate to reach out to our Protected Crop Specialist, Talia Plaskett.