Substrates

Soilless Substrates

- Until the 1960s, greenhouse substrates consisted of a mixture comprised of loam, organic material, and sand
- Soilless substrates became popular because of:
    - reduced pathogen infestation
    - lighter in weight and less transportation cost
    - easy customization
    - relatively uniform composition

- Functions of a soilless substrate:
    - reservoir for plant nutrients
    - water retention
    - aeration to roots
    - anchorage for plant

Pore space is an important characteristic of soilless substrates

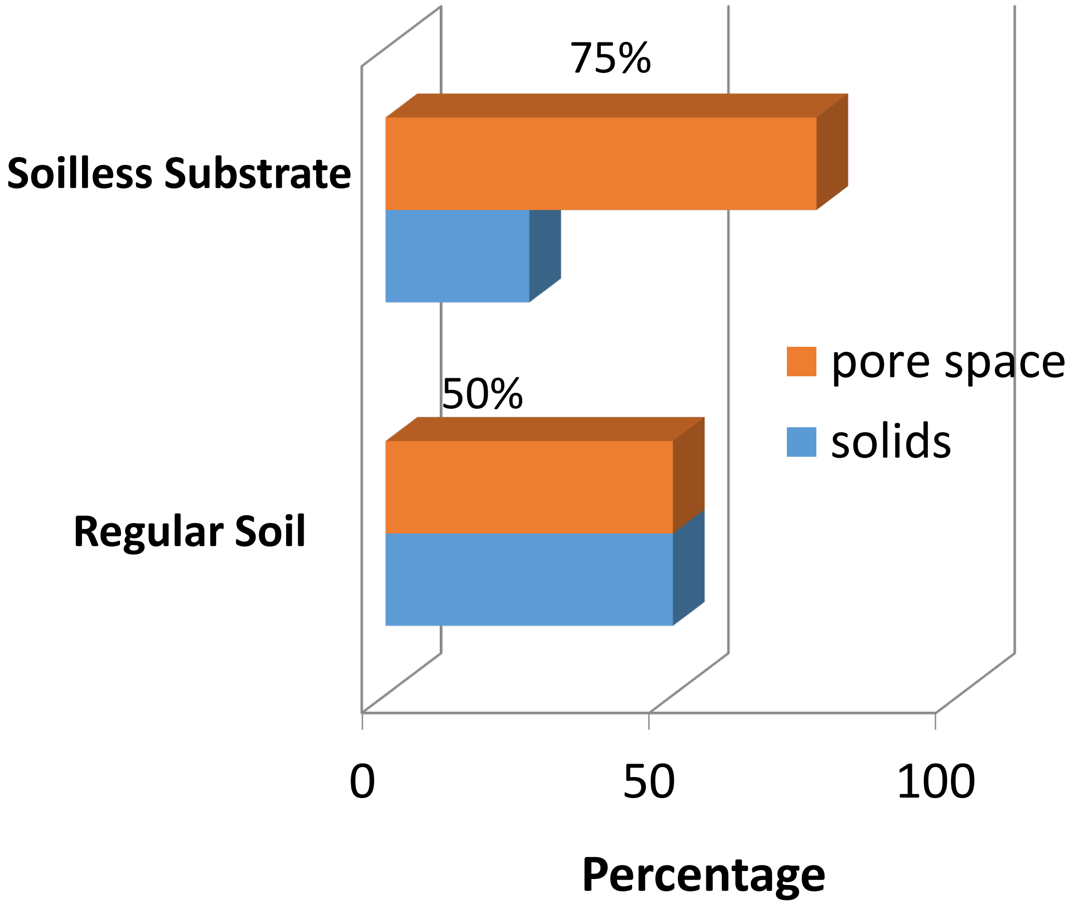
- Substrates contain solid matrix and pores

- Pore space is occupied by air and water

- **Porosity (%)** is the proportion of pore volume to total substrate volume

- Wide pores are good for air exchange while narrow pores hold more water

- Balancing air and water contents in the pore space is vital. Ideally, 25% of pore space should be filled with air



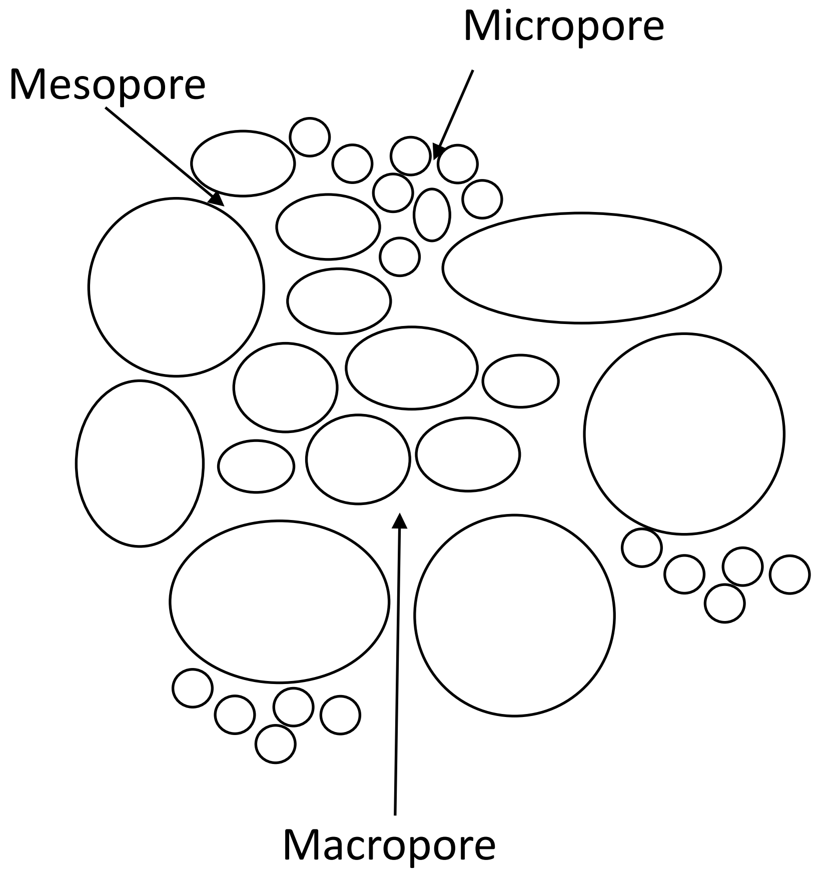
Water and air space of soilless substrates

Component	Peat + Bark + Perlite + Vermiculite (P-B-P-V)	Peat + Perlite (P-P)
Solids (%)	40.9	38.6
Porosity (%)	59.1	61.4
Water space (as % total pore space)	72	62
Air space (as % total pore space)	28	38

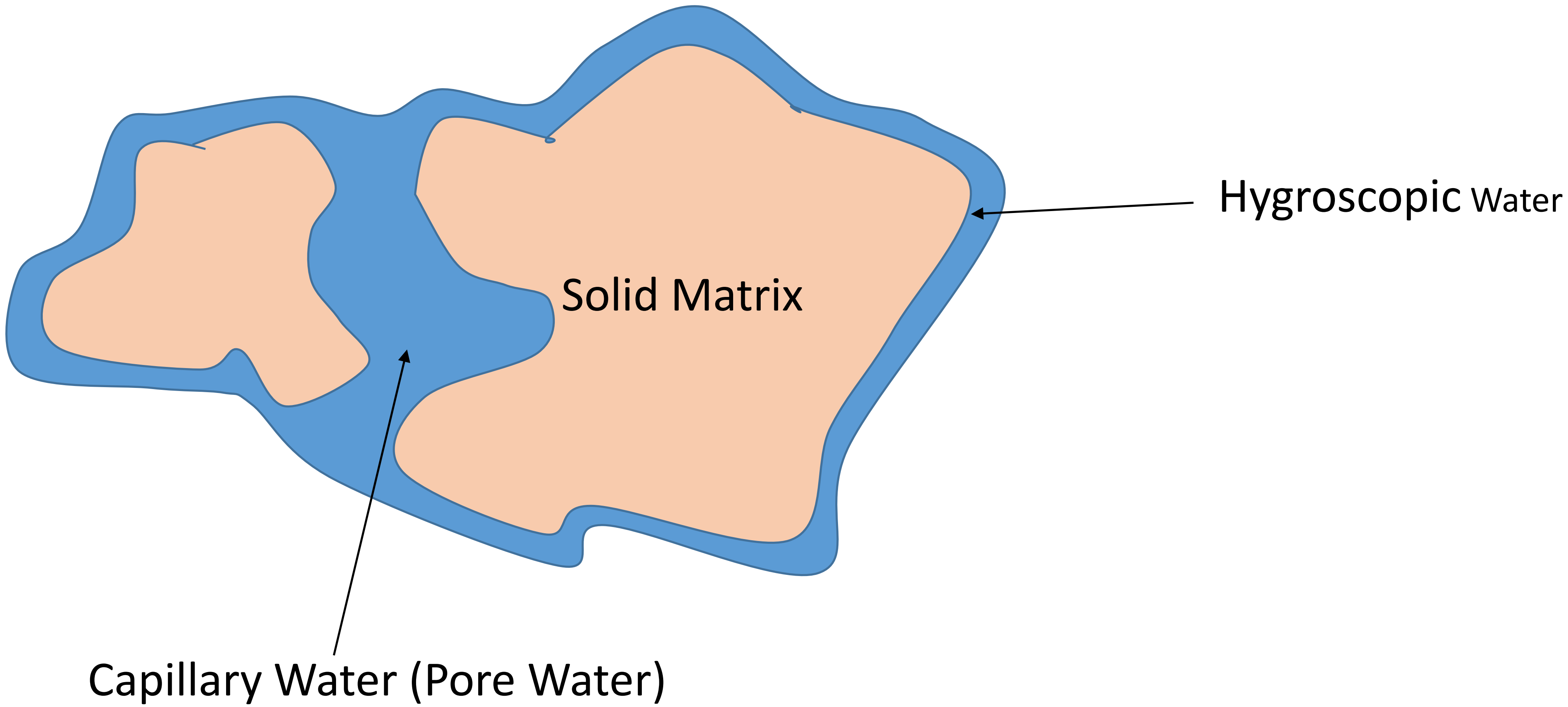
Different types pores in a soilless substrate

Macropores: radius > 0.0075 cm
Mesopores: radius between 0.0075 to 0.003 cm
Micropores: radius between 0.003 to 0.0003 cm

- Macropores increase drainage and air volume inside a substrate
- Water is held mostly in mesopores and micropores

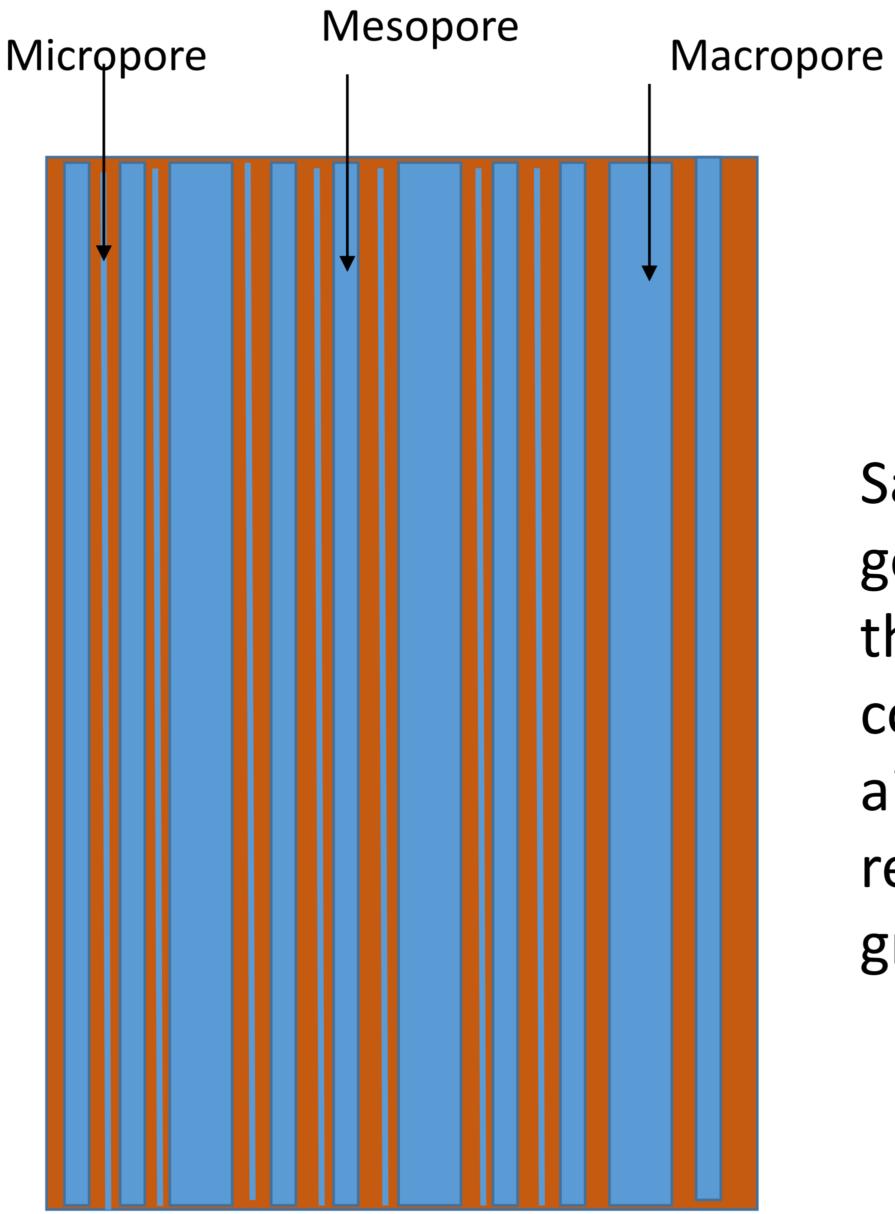


Why pores are important?

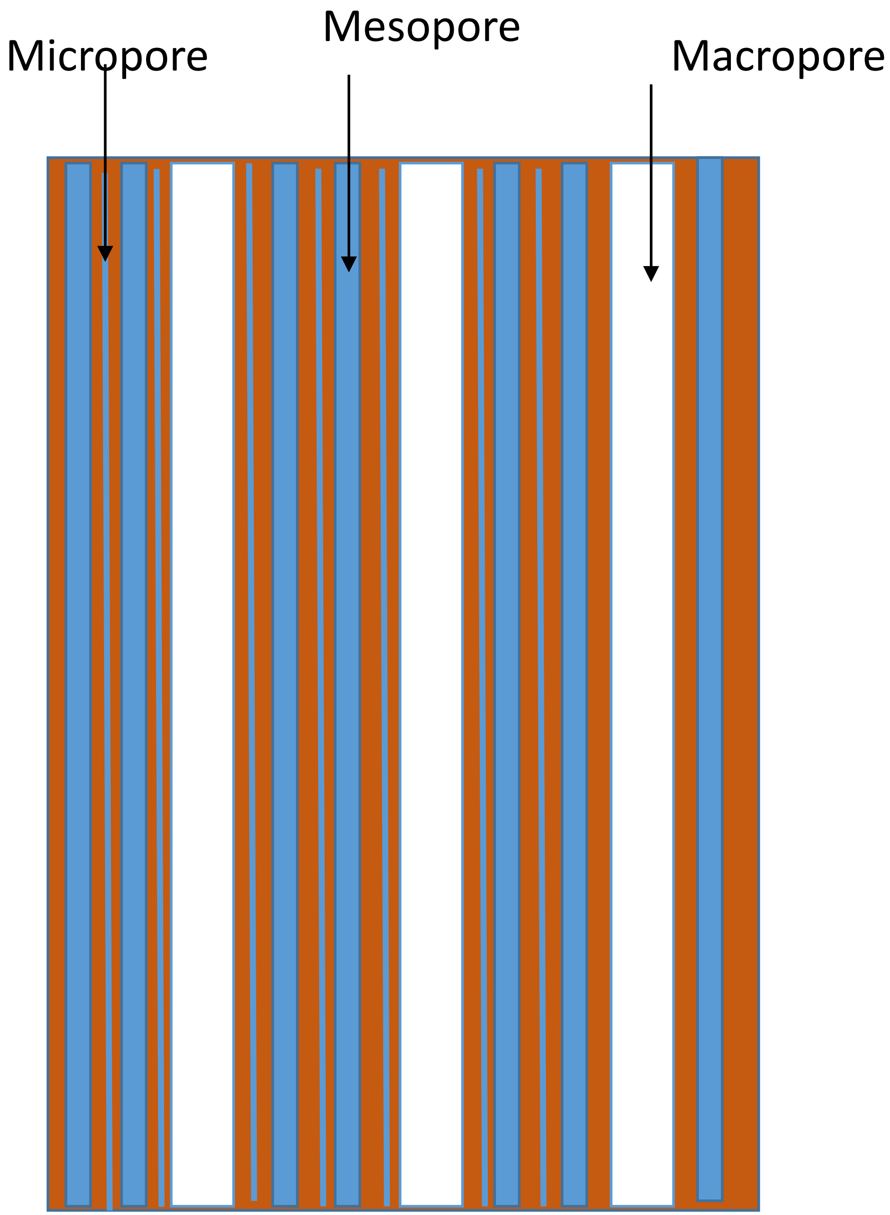


Capillary water is extracted easily by plant roots whereas it is difficult to separate water molecules held hygroscopically to solid matrix

Saturation
(all pores are filled with water)



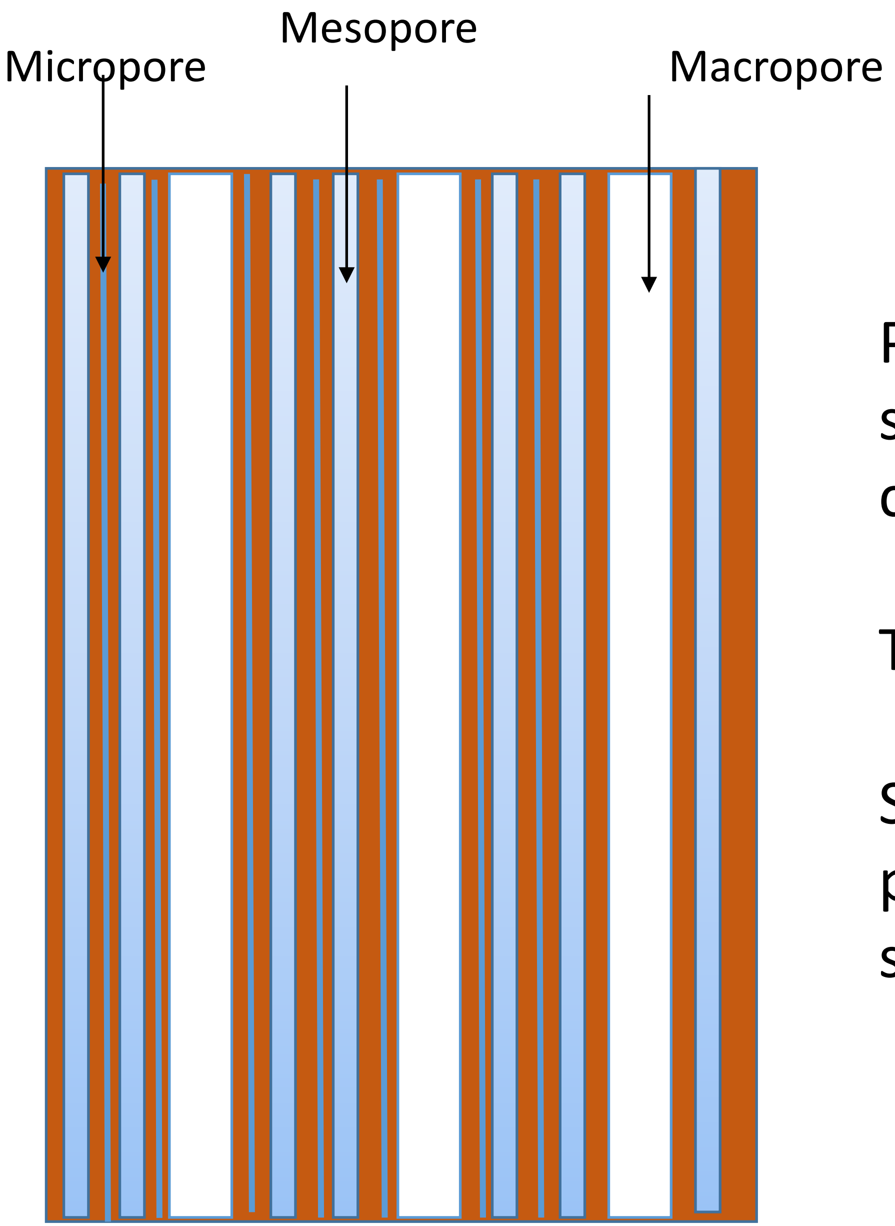
Container Capacity
(macropores are drained and filled with air)



Saturation is not good for plants as the substrate is completely devoid of air or oxygen required for root growth

Wilting point

(most of the water in mesopores is used; micropores may carry water)



Plants absorb water held in the substrate between container capacity and wilting point

This is called ‘available water’

Some water is not extracted by plant roots and will be left in the substrate as ‘unavailable water’

Pore size distribution in soilless substrate (peat-perlite) and soil (loamy sand)

Pore	Soilless	Soil
Macropores (%)	19.4	0.4
Mesopores (%)	13.4	69.0
Micropores (%)	67.2	30.6

- Larger macropore space and smaller mesopores space in soilless substrates rapidly decreases hydraulic conductivity or ease with which water can move through pores. This creates dry pockets.
- Increased micropore space rapidly increases overall tension with which water is held by the solid matrix (or matric pressure) at low volume of water in the substrate
- Collectively rapidly decreasing hydraulic conductivity and higher matric potential makes plants wilt quickly in soilless substrates

Substrate Chemical Properties

Electrical Conductivity (EC): A measure of the total amount of dissolved fertilizer ions in the solution held by substrate pores

pH: A measure of the acidic or basic nature of the solution held by substrate pores. A pH of 5.5 to 6.5 is optimal.

Cation Exchange Capacity (CEC): It is the ability of the substrate to adsorb and release cations (positively charged ions, Ca, Mg, Al, Fe, Zn, etc.)

Anion Exchange Capacity (AEC): It is the ability of the substrate to adsorb and release anions (negatively charged ions, NO3-, PO4-, etc.). AEC is less in soilless substrates

Carbon to Nitrogen Ratio (C: N): The percentage of carbon to nitrogen in a substrate. Affects microorganism growth and decomposition. A high C:N ratio immobilizes nitrogen in the substrate (becomes unavailable for plants). Better to keep C:N ratio at 40 to 60: 1

Components of a soilless substrate

1. Peat Moss

- Mostly used is sphagnum moss
- N content 0.5 to 1.5%
- High water holding capacity and good aeration, good surface area
- pH of peat is acidic (3.0 to 4.0), limestone is added to reduce acidic effects
- C:N ratio is slightly high (60 : 1) but decomposition is slower
- CEC is good but poor AEC

There is increasing opposition to using peat moss as it may take centuries for restoring peat bogs and its ability to act as a carbon sink

2. Coir

- Extracted from the outer husk of the coconut
- Chemical and physical properties closer to peat
- Holds slightly less amount of water than peat but better aerated
- Less shrinkage, C: N ratio is 80: 1; lignin in fiber resists microbial decomposition
- Easy to rewet than peat
- pH is 5 to 6.5, thus better range than peat
- Lower CEC than peat
- Issues: Source to source variability exists, sometimes high salt content

3. Vermiculite

- Mica like silicate mineral
- It contains layers of thin plates with moisture in between layers
- When heated moisture becomes steam and makes the plates move further apart, resulting in an open accordion-like structure
- Holds moisture and cations between spaces and on the surface
- Slight to moderately alkaline, thus makes a good mix with peat
- Good CEC and aeration properties for vermiculite
- Usually added up to 20% of the total volume

4. Perlite

- Siliceous volcanic rock that when heated to 1800 °F, expands to form white particles with air-filled spaces
- Good for aeration and light in weight
- Inert material, negligible CEC
- pH is alkaline
- Water will adhere to the surface but not be absorbed by perlite

5. Rockwool

- Prepared by blowing jet of steam through molten rock or spinning molten rock to form fibrous material
- Water retention is high and has good aeration
- Used as slabs in hydroponic industry or mixed with peat
- Slightly alkaline
- Inert with negligible CEC
- Neither contributes nor holds nutrients
- Some individuals have skin sensitivity to Rockwool