PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Characteristics of Soilless Substrates

Petrus Langenhoven, Ph.D.
Horticulture and Hydroponics Crops Specialist
January 10, 2017

PURDUE UNIVERSITY

1

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Outline

- **Container Media**
  - … Advantages
  - … Properties
- **pH, EC and Alkalinity**
  - … Irrigation water Quality
  - … Alkalinity

PURDUE UNIVERSITY

2

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Container Media

PURDUE UNIVERSITY

3

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Advantages of Using Growth Media Instead of Soil

- No need for arable land
- Light weight
- Total control over root environment
- Precise irrigation scheduling
- Improved crop uniformity
- Limits root disease
- Lower environmental impact

PURDUE UNIVERSITY

Purdue University is an equal access/equal opportunity institution.

4

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

What Constitutes a Good Growing Media?

Physical and Chemical properties

a) Nutrient retention
- low soluble salts content, but need to have an adequate cation exchange capacity. pH should be between 5.0 and 6.5

b) Gas exchange/aeration and porosity
- High total porosity (60-85%), sum of all the space in the macro-pores and micro-pores
- Aeration (10-20%), large particles - more aeration and less water holding capacity

c) Water retention and drainage
- Porous and well drained, but must retain enough moisture between irrigations (50-65%) to satisfy plant water requirements

d) Biologically and chemically stable
- Organic substrates need to be well composted - no nitrogen negative period at the onset of production
- Inorganic substrates that are inert and well composted organic substrates work best.

PURDUE UNIVERSITY

5

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

What Constitutes a Good Growing Media?

Physical and Chemical properties….continue

e) Standardized and uniform batches
- Allow grower to use standardized production practices, such as fertilization and irrigation, with every crop.

f) Free from harmful soil pathogens
- Inorganic substrates like rockwool and perlite are sterilized by virtue of the production process

Shape and volume of the container, affects water-holding capacity

Cost and availability

Irrigation equipment and strategy, adapt according to physical properties of substrate

Environmental impact

PURDUE UNIVERSITY

6

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Popular Container Media/Substrates

Inorganic Media		Organic Media
Natural	Synthetic	
Sand	Foam mats (Polyurethane)	Sawdust
Gravel	Polystyrene Foam	Pine Bark
Rockwool	"Oasis" (Plastic Foam)	Wood chips
Glasswool	Hydrogel	**Sphagnum Peat moss**
Perlite	Biostrate Felt® (Biobased Product)	**Coir** (Coconut Peat/Fiber)
Vermiculite		Rice Hulls
Pumice		
Expanded Clay		
Zeolite		
Volcanic Tuff		

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

pH of Different Media | Cation Exchange Capacity

Materials	Average	Range
Wood fibre	4.8	3.8–5.4
Expanded clay granules	8.1	7.7–8.6
Coir chips	5.7	5.4–6.1
Coir dust	6.2	6.0–6.7
Perlite	6.3	5.2–7.7
PU-foam	6.6	4.7–8.9
Pumice	6.3	4.7–7.6
Rock wool	6.2	5.2–7.8
Peat	3.9	3.4–4.4

Table 11.9 The pH of different substrates and substrate constituents as given by Kipp et al. (2000)

CEC - Capacity to hold and exchange mineral nutrients

Table 11.10 Cation exchange capacities (CEC) of some substrates and substrate constituents expressed as C^{+} mmol kg^{-1} dry matter

Material	CEC	References
Humus	2000	Bunt, 1988
Peat	560–1580	Lamaire, 1995; Lamaire 1998; Puustjärvi, 1977
Coir dust	350–600	Evans et al., 1996; Verhagen, 1999
Sawdust (fresh)[1]	100	Jokova et al., 1997
Compost (fresh)	270–1080	Jokova et al., 1997; Lamaire, 1998
Compost (stable)	640–1810	Chen et al., 1989; Jokova, et al., 1997; Lamaire, 1998
Clay[1]	100–300	RHP, 2007
Vermiculite[1]	390–530	Van der Mark, 2008
Perlite	10–70	Bunt, 1988; Gizas et al., 2001; Lamaire, 1995
Zeolite	400–1200	Stamatakis, 2001; Maloupa, 2002
Tuff[2]	70–600	Silber et al., 1994
Pumice	60–80	Gizas et al., 2001
Rockwool	0	Lamaire, 1995

[1] See text; [2] Within pH 4.0–7.0.

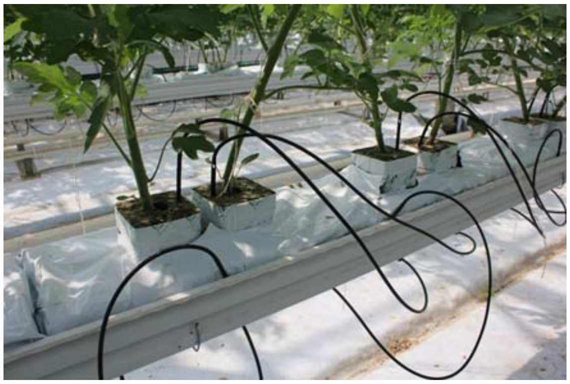
C. Sonneveld, W. Voogt, *Plant Nutrition of Greenhouse Crops*, DOI 10.1007/978-90-481-2532-6_11, © Springer Science+Business Media B.V. 2009

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Rockwool

- 60% diabase (form of basalt rock, dolerite), 20% limestone, and 20% coke
- Melted at 2912°F, spun at high speed into thin fibers
- Heated with phenolic resin and wetting agent to bind them together and lower the natural hydrophobicity of the material. Pressed into slabs
- Characteristics:
  - Low bulk density and high porosity
  - High water-holding capacity (80%) and good aeration
  - Chemically inert with pH 7.0 to 8
  - No CEC or buffering capacity
  - Dissolve at low pH, below 5.0
  - Reusable. Can last for up to 2 seasons



PURDUE UNIVERSITY

9

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Coconut Coir

- Coconut fiber/dust is an agricultural waste product derived from husk of coconut fruit
- Alternative to peat moss
- Composted for 4 months
- Characteristics:
  - Can have high amounts of salts
  - Good aeration and water-holding
  - Water and air content varies according to texture components
    - More fiber – High air and lower water content; Fiber, TPS 98% and AFP around 70%
    - More peat – a lot of water and little air; Coir dust, TPS 86-94% and AFP 9-14%. Relatively high EAW at around 35%

Photo: http://blog.hooksandlattice.com/2013/03/12/what-is-coconut-coir/

PURDUE UNIVERSITY

Purdue University is an equal access/equal opportunity institution.

10

Coconut Coir

- Coir is hydrophilic, disburse evenly over surface of fibers
- Higher pH than peat moss, pH is 5.6 to 6.6
- Not inert and can store lots of nutrients, high CEC
- Require more Ca, S, Cu and Fe than peat moss. Greater N-immobilization than peat moss
- May contain excessive levels of K, Na and Cl. Soak and rinse well before use
- More lignin and less cellulose than peat, more resistant to microbial breakdown
- May shrink less than peat
- Easier to re-wet than peat
- Can be inoculated with beneficial microbes
- Use for up to 2 - 3 years

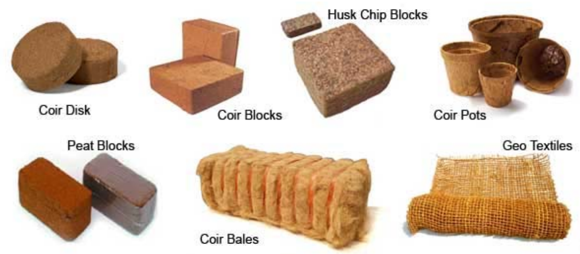
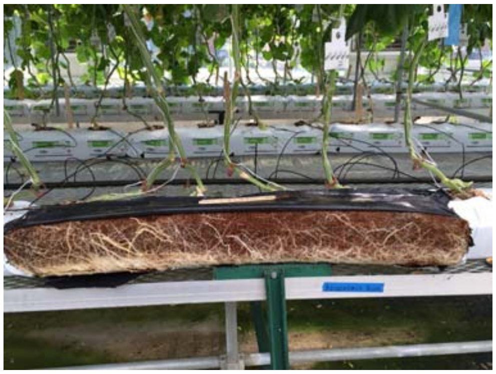


Photo: www.greenpeatcoco.com

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Coconut Coir Slab



PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Perlite

- Naturally occurring, nonrenewable, inorganic, siliceous volcanic rock
- Grinded and popped at ±1800°F. Expands to between 4 and 20 times larger
- Characteristics:
  - Lightweight, sterile, white, porous aggregate
  - Finished product is a "closed cell" that does not absorb water. Water will adhere to surface
  - Usually included in mixture to improve drainage or increase aeration
  - Neutral pH of between 6.5 and 7.5
  - Low CEC
  - Chemically inert

PURDUE UNIVERSITY

13

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Vermiculite

- It's a mica-like, silicate mineral
- Contains mineral water between ore plates
- When heated at 1832°F, ore plates move apart into an open, accordion-like structure

www.dupreminerals.com

http://fpsc.wisc.edu/growguide/covering_seeds.shtm

PURDUE UNIVERSITY

Purdue University is an equal access/equal opportunity institution.

14

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Vermiculite

- Characteristics:
  - Very light, high water retention and good aeration
  - Low bulk density
  - pH value is 7 to 7.5, and low EC
  - Low pH can release Al into the solution
  - Has a permanent negative electrical charge, and therefore CEC is high
  - High nutrient content (K, Ca and Mg)
  - Used as component of mixes and in propagation, to increase water-holding capacity

Photo: https://www.linkedin.com/pulse/facts-vermiculite-gil-strachan

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Sphagnum Peat Moss

- Partial decomposition of sphagnum, other mosses and sedges
- Available in different colors, indicate degree of decomposition
- Light-colored peat, larger particles and limited decomposition. Provides excellent aeration and decomposes more rapidly than black peat
- Black peat is highly decomposed, physical properties vary greatly

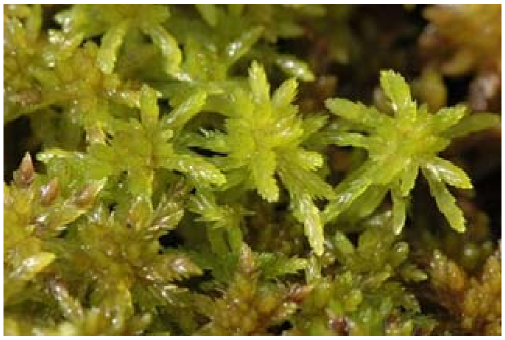


Photo: https://commons.wikimedia.org/wiki/File:Sphagnum.flexuosum.jpg

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Sphagnum Peat Moss

- Characteristics:
  - Light weight
  - High water-holding capacity
  - Good air capacity
  - Naturally acid with pH value between 3.0 to 4.0
  - Low nutrient content, but high CEC
  - Stable structure
  - Naturally hydrophobic when dry; wetting agent must be used
  - Slumping and shrinkage can be a potential constraint

Photo: www.canadianpeatmoss.com

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Photos: www.lambertpeatmoss.com

Sphagnum Peat Moss

Characteristics	Light peat	Dark peat	Black peat
Organic matter (% d.m.)	94–99	94–99	55–75
Ash (% d.m.)	1–6	1–6	23–30
Total porosity (% vol.)	84–97	88–93	55–83
Water-holding capacity (% vol.)	52–82	74–88	65–75
Volume weight (g/cc)	0.06–0.12	0.14–0.20	0.32–0.40
Cation exchange capacity (meq/100 g)	100–150	120–170	80–150
Total nitrogen (% d.m.)	0.5–2.5	0.5–2.5	1.5–3.5
C/N ratio	30–80	20–75	10–35
pH in water	3.0–4.0	3.0–5.0	5.5–7.3
Degree of decomposition[a]	H1–H3	H4–H6	H7–H10

PURDUE UNIVERSITY

Source: GAPs for greenhouse vegetables crops: Principles for Mediterranean climate areas. FAO, 2013

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

EC, pH and Alkalinity

PURDUE UNIVERSITY

19

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Greenhouse Irrigation Water Quality Guidelines

	Upper Limit	Optimum Range	Comments
pH	7.0	5.5 – 6.5	
EC	1.25 mS·cm^{-1}	Near zero	0.75 mS·cm^{-1} for plugs and seedlings. High EC can be the result of accumulation of a specific salt which can reduce crop growth
Total Alkalinity (as $CaCO_3$), acid-neutralizing or buffering capacity	150 mg·L^{-1}	0 – 100 mg·L^{-1}	Measures the combined amount of carbonate, bicarbonate and hydroxyl ions. 30 – 60 mg·L^{-1} are considered optimum for plants pH 5.2, 40 ppm alkalinity; pH 5.8, 80 ppm alkalinity; pH 6.2, 120 ppm alkalinity
Hardness (amount of dissolved Ca^{2+} and Mg^{2+})	150 mg·L^{-1} >60 mg·L^{-1} Ca >25 mg·L^{-1} Mg	50 – 100 mg·L^{-1}	Indication of the amount of calcium and magnesium in the water. Calcium and magnesium ratio should be **3 – 5 mg·L^{-1} calcium to 1 mg·L^{-1} magnesium**. If there is more calcium than this ratio, it can block the ability of the plant to take up magnesium, causing a magnesium deficiency. Conversely, if the ratio is less than 3-5 Ca:1 Mg, the high magnesium proportion can block the uptake of calcium, causing a calcium deficiency. Equipment clogging and foliar staining problems above 150 ppm
Bicarbonate Equivalent (HCO_3^-)	122 mg·L^{-1}	30 – 50 mg·L^{-1}	Help to stabilize pH. Increased pH and can lead to Ca and Mg carbonate precipitation

mg·L^{-1} = ppm

PURDUE UNIVERSITY

Purdue University is an equal access/equal opportunity institution.

20

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Factors Affecting Root Media pH

- Acidic Media
  - … pH less than 7….Sphagnum peat moss, coir
- Neutral Media
  - … pH around 7….Perlite
- Alkaline Media
  - … pH greater than 7….Vermiculite, rockwool
- Alkalinity of the water (carbonates/bicarbonates). High alkalinity will increase container media pH over time
- Ammonium or urea based fertilizers will acidify the root media
- Fertilizers that are nitrate based tend to increase root media pH over time
- Media pH can be altered prior to planting with Limestone ($CaCO_3$) or Dolomite (50% $CaCO_3$ and 40% $MgCO_3$)

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

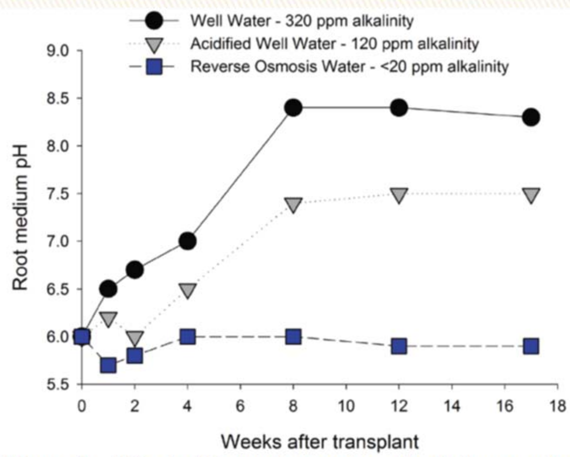


Figure 1. Effect of irrigation water alkalinity on substrate pH over time. Each irrigation included water soluble fertilizer (97% nitrate N at 200ppm). Source: Adapted from research by Bill Argo and John Biernbaum at Michigan State University (unpublished work).

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

Information Resources

University resources – Extension publications

Professional magazines

- Greenhouse Grower, www.greenhousegrower.com
- Practical Hydroponics and Greenhouses, www.hydroponics.com.au
- Greenhouse Canada, www.greenhousecanada.com

Books

- Greenhouse Technology and management, Nicolas Castilla
- Greenhouse Operation and Management, Paul V. Nelson
- Soilless Culture, Michael Raviv & J. Heinrich Leith
- Growing Media for Ornamental Plants and Turf, Kevin Handreck & Niel Black
- Plant Nutrition of Greenhouse Crops, Cees Sonneveld & Wim Voogt
- Hydroponic Food Production, Howard M. Resh

Trade shows and conferences

- Indiana Small Farm Conference, March 2-4, 2017 – Danville IN
- Indoor Ag Con, May 3-4, 2017 – Las Vegas NV
- Cultivate'17, July 15-18, 2017 – Columbus OH

Manufacturers and distributors (list is not complete but it's a good start):

- http://www.tunnelberries.org/single-bay-high-tunnel-manufacturers.html
- http://www.tunnelberries.org/multi-bay-high-tunnel-manufacturers.html

PURDUE UNIVERSITY

PURDUE EXTENSION | HORTICULTURE & LANDSCAPE ARCHITECTURE

THANK YOU Questions?

Contact details:

Dr. Petrus Langenhoven
Horticulture and Hydroponics Crop Specialist
Department of Horticulture and Landscape Architecture
Purdue University
Tel. no. 765-496-7955
Email: plangenh@purdue.edu

PURDUE UNIVERSITY