The Nuts and Bolts of Keeping Your Roots!

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We grow plants with an incredible diversity of root sizes and structures in artificial systems that restrict roots!

High Root Temperatures Kill Roots!
- High root temperatures kill roots (especially on the southside) throughout the US.
- Media temperatures get hotter than we realize!
- Root death reduces plant growth, and increases fungicide and labor costs.

We grow plants in mostly black containers throughout the greenhouse and nursery industries. In addition, we grow plants in containers in greenhouse vegetable production.

Media Temperature Gets Hot!

We were surprised to find that media temperatures in MN exceeded those in SoCal at times!

Temperature-Stressed Roots Limit Above-Ground Growth

Klock et al. 1997
Root Mass Gain Decreased at Root Temperatures Between 35 and 50°C

Proportional EL was Impacted by an Interaction Between Temperature and Variety

*Plant height decreased at temperatures above 40 and 45°C*
Increasing RT Impacted Above & Belowground Growth

High Root Temperature Exposure Reduced Pn

Temperature (T) = ‘***’
Variety (V) = ‘n.s.’
Measurement Day (MD) = ‘n.s.’
T x V = ‘n.s.’
T x MD = ‘n.s.’
V x MD = ‘n.s.’
T x V x MD = ‘n.s.’

HRT and Measurement Day Impacted gs

Temperature (T) = ‘***’
Variety (V) = ‘n.s.’
Measurement Day (MD) = ‘***’
T x V = ‘n.s.’
T x MD = ‘***’
V x MD = ‘n.s.’
T x V x MD = ‘n.s.’

‘n.s.’ indicates P > 0.05, ‘*’ indicates P < 0.05, ‘**’ indicates P < 0.01, ‘***’ indicates P < 0.001.

Shoot Mass Gain Decreased at Root Temperatures Between 35 and 50°C

Both pot height and diameter influence how much aeration is available to roots. Large diameter-shallow pots have the least free pore space, and small diameter-tall pots have the most free pore space.

Do we routinely over-water? Multiple day waterings on hot days will reduce free pore space. In addition, the amount of O₂ that water can hold decreases as temperature increases. Are we ‘drowning’ roots when we water on hot days?
Is lack of O₂ the basis for this problem we commonly see on some plug crops? Wet/dense media will result in poor rooting on vinca, gerbera and impatiens.

Reducing Pot Temperature
- Alternative container materials
- Alternative container colors
- Blocking solar radiation
- Bed surface material

Take Home Messages
1) Don't let media temperatures exceed 95°F if you can help it.
2) Warm root temperatures for over 7 days especially reduces rooting.
3) Water with a wet-dry cycle. Over-watering, or watering to frequently when it is hot may be drowning roots.
4) Tall pots are always better for roots than shallow pots!
5) Gravel helps cool pots. Should we be dropping our black pots into white pots during the summer?
6) Space crops as late as possible during the summer, and only after plants root in.

Root Rots
- Rhizoctonia
- Pythium
- Phytophthora
- Thelaviopsis
- Sclerotinia
- Sclerotium
- Fusarium

Rhizoctonia (Damping off)
- Attaches at the root/media interface.
- The fungus often grows on the media surface – especially when germinating seed.
- Can cause stem cankers (dry appearance) above the media when humidity is high.
- Encouraged by warm temperatures and wet conditions.
- Plants can suddenly wilt and topple.
Pythium and Phytophthora

- Easily spread through irrigation water and dust.
- Attacks from root tips and moves up.
- Infected plants may wilt on sunny days even though media is wet.
- Prevalent under cool-wet conditions.
- Outer root cortex separates from root core.
- Roots are discolored from the tips up.

Phytophthora

- Common in Vinca, Calibrachoa, and Mandavillea, and Rosemary.
- Proliferates under warm, wet and humid.
- It is hard to distinguish between root and stem infection.
- Can infect foliage as well - Mandavillea.

Calibrachoa can suddenly wilt soon after planting. Often this will happen within the first 2 weeks. Other plants in the pot can appear to be completely healthy.

What Works?

- Chipco 26019 *
- Cleary's 3336 **
- Medallion ***
- Pageant ***
- Terrachlor 400 ***
- Affirm WDG ***
- Empress ***
- Heritage **
- Plantshield * (preventative)
**Pythium/Phytophthora - What Works?**

- Subdue MAXX ***
- Aliette **
- Truban/Terrazole ***
- Fenstop **
- Segway **
- Alude **

**Thelaviopsis**

- Common name is ‘black root rot’
- Proliferates when media pH > 6.2 (even for a short period!)
- ‘Uneven’ growth between among adjacent plants with infected plants appearing stunted with lower leaf edge yellowing and adjacent plants completely healthy.
- Common on pansies, garden mums and vinca. Other crops affected include calibrachoa, bacopa, begonia, browallia, and verbena.
- Overwinters.

**Thelaviopsis - What Works?**

- Medallion WSP **
- Clearys 3336/OHP 6672 ***
- Terraguard ***
- Tourney ***

There is some recent evidence that Cleary’s 3336 may cause phytotoxicity in tomato when media temperatures exceed 86°F.
Fusarium

- Common on bulbs, grasses, liriope, mondo grass, succulents, cyclamen, and perennials with a ‘crown’.
- Stem cankers on Mandavilla and Kalanchoe
- Proliferates when warm and wet – especially during summer.
- Major disease of commercial vegetable production (basis for much grafting).

Medallion should always be used regularly on perennials to control Fusarium.

Fusarium - What Works?

- Medallion WSP ***
- Terraguard/Trinity **
- Heritage/Compass ***
- Chipco 26019 **
- Clearys 3336 **

General Fungicide Drenches

For Pythium + Phytophthora Control
- Subdue MAX
- Aliette
- Segway
- Truban

For Rhizoctonia + Fusarium Control
- Cleary’s 3336
- Chipco 26019
- Compass or Heritage
- Medallion

Some organisms (fungi/bacteria) can form a symbiotic relationship with plants' roots that can:
- Increase nutrient absorption
- Increase drought tolerance
- Increase disease resistance

**Beneficial Microbes: The Contenders**

- **Fungi**
  - *Trichoderma harzianum* ‘THTs’
  - *Curvularia protuberata* ‘Cp6660D’
  - *Glomus intraradices* (Mykos)

- **Bacteria**
  - *Azospirillum brasilense* (Azos)
  - *Bacillus amyloliquefaciens* (Hydroguard)

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<table>
<thead>
<tr>
<th>Inoculants Didn't Increase Dry Mass Gain Across RT</th>
<th>Shoot Dry Mass Gain (g)</th>
<th>Root Dry Mass Gain (g)</th>
<th>Total Dry Mass Gain (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Un-Inoculated</td>
<td>1.91 AB</td>
<td>0.19 AB</td>
<td>2.10 AB</td>
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<tr>
<td><em>Azospirillum brasilense</em></td>
<td>1.90 AB</td>
<td>0.17 A</td>
<td>2.08 AB</td>
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<tr>
<td><em>Bacillus amyloliquefaciens</em></td>
<td>1.84 AB</td>
<td>0.20 AB</td>
<td>2.05 AB</td>
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<tr>
<td><em>Curvularia protuberata</em></td>
<td>1.66 A</td>
<td>0.17 A</td>
<td>1.82 A</td>
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<tr>
<td><em>Glomus intraradices</em></td>
<td>2.13 B</td>
<td>0.21 B</td>
<td>2.34 B</td>
</tr>
<tr>
<td><em>Trichoderma harzianum</em></td>
<td>1.76 AB</td>
<td>0.16 A</td>
<td>1.94 AB</td>
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</tbody>
</table>

Developing a modular vegetable greens production system. We aimed to integrate a solar panel with energy storage with LED panels to grow cool temperature tolerant greens that could be grown in a home basement.

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I am moving to Maryland!
University of Maryland – College Park

- 352,000 alumni
- 3 Nobellaureates, 2 Pulitzer Prize, 3 Emmy and 2 Tony award winners
- Research Funding 2018: $545 million (4th nationally)
- Ranked:
  - #22 Public research institution
  - #15 Most innovative school
  - #9 Entrepreneurship
  - #6 in research output among public universities

Department of Plant Science and Landscape Architecture

- 51 faculty
- 53 Graduate students
- Approx. 200 undergraduate students

- Horticulture
- Agronomy
- Plant Biology
- Plant Pathology
- Landscape Architecture

Using pathogens to fight pathogens!

Using new LED lighting technologies combined with molecular genetics to answer fundamental questions in plant physiology.
University of Minnesota Partners

- Minnesota Greenhouse Growers and the Minnesota Agriculture Experiment Station
- Floriculture and Nursery Research Initiative (USDA-ARS) administered by SAF-AFE and HRI

Grower Partners:
- Altman Plants, Inc.
- Rocket Farm, Inc.
- Smith Greenhouses, Inc.
- Green Circle Growers, Inc.
- Wagner’s Greenhouse
- Go Green Agriculture