Plant Water Stress

- Drought stress is the most significant environmental stress resulting in crop loss
- ‘Agricultural Drought’ – lack of adequate moisture for crops to complete normal plant development and crop maturity
  - Meteorological drought – prolonged lack of precipitation
  - Increased evapotranspiration rates

Impact of Water Stress on Crop Development

- Compressed growth cycle
- Reduced rate of cell division and expansion
- Reduced leaf size
- Reduced stem elongation
- Reduced root proliferation
- Reduced fertilization
- Disturbed stomatal oscillations
- Compromise nutrient balances

Soil – Plant – Atmosphere Continuum

- There is a continuous water column
  - Soil-Plant-Air
  - Root uptake is junction between soil-plant
  - Root health, depth, growth
  - Evapotranspiration is the junction between plant-atmosphere
    - Stomatal conductance is the ‘valve’
- Column is under constant tension
- The water status is affected by any change in conditions in the soil, plant or atmosphere

Soil: Plant Available Water

- A healthy soil has: pore space free of water and sufficient movement of gases through soil profile
- Permanent Wilting Point – plant is unable to extract water from the soil matrix
  - May still be lots of water in the soil

Leaf Vapour Pressure Deficit

- Water movement through the column is driven primarily by transpiration
- Difference in vapour pressure between the leaf air and ambient air
- Driven by:
  - Solar radiation
  - Wind speed
  - Turbulence
  - Humidity
Plant Water Stress - Dr. Rebecca Harbut (KPU)

Leaf RH 99.6%, Air RH 96% @ 20°C
VPD = 56 kPa (725 PSI)

On a drier day: Air RH 50% @ 20°C
VPD = 93 kPa (13,488 PSI)

Typically transpire between 100 and 1000 g of water per gram dry mass formed (less under humid conditions, more under dry conditions).

4 Factors that reduce hydraulic conductivity...

1. Root/soil shrinkage
   • Roots and soil pull away from each other reducing the hydraulic (wet) linkage
   • Severity impacted by soil type – most severe in clay soils

2. Solute accumulation at root surface
   • High rates of transpiration
   • Low rainfall
   • Fertilizer application
   • High tunnels

3. Physiological reduction in root hydraulic pressure
   • Low temperatures
   • Drought stress
     • ‘stress phytohormone’ production – Abscisic acid
     • Allows drought conditions sensed in the roots to be signaled to the leaves before leaves sense drought conditions

4. Physiological reduction in root hydraulic pressure
   • Water stress increases production of ABA
   • Produced in roots
   • Reduces stomatal conductance
   • Drought stress will trigger signal to shorten crop growth cycle

Richmond farmer Bill Zylman shows how the top of the soil crumbles, but moisture is only a few inches below the surface of his potato field.

Chung Chow, Business Vancouver, July 2015

Plant Temperature

• Transpiration is the cooling mechanism for plants
• Plant and Fruit temperature quickly rises in water stress conditions

Abcisic Acid (ABA) – Stress Hormone

Source: Lyn Jones, Uof Dundee
http://www.lifeb.dundee.ac.uk/people/lyn-jones

30°C
20°C
10°C
0°C

https://labs.mcds.ucsb.edu/finkelstein/ruth/
4 Factors that reduce hydraulic conductivity...

4. Xylem Emboli
   - Under very large water xylem tension, water column may ‘snap’
   - Loss of water through transpiration is not matched by root uptake
   - Gas filled cavities
   - Plants native/adapted to humid regions are much more prone to cavitation than plants from more arid environments

Impact of Water Stress

- Factors that influence the impact of water stress:
  - Duration and intensity of water stress
  - Crop phenology
  - Crop genotype

Acclimation to Drought Conditions

- Plants exposed to drought express morphological and physiological changes:
  - Decreased leaf expansion
  - Senescence of older leaves
  - Increased cuticle thickness
  - Increased root extension into deeper soil
  - Accumulation of solutes in the root cap to decrease osmotic potential

Loss of Turgor Pressure

- Wilting
  - Plasma membrane pulls away from cell wall

Water Vs. Carbon

- Water and CO₂ exchange are linked – water conservation = reduced C uptake
- carbon uptake is critical for growth

Timing is Everything...

- Phenological stages differ in their sensitivity to water stress
  - Many annual crops are most sensitive to water stress during and immediately after flowering
    - Reduced pollen viability
    - Death of flowering
Phenological Stages of Growth: Early Season

- Crop Establishment
  - Significantly reduce germination by affecting imbibition
  - Poor stand establishment reduces yield
- Many annual crops are most sensitive to water stress during and immediately after flowering
  - Reduced pollen viability
  - Death of flowering

Tomato Drip Irrigation

- EPK – reference evapotranspiration
- ECC - ET x K (Estimated Crop Canopy Coverage)
- SMD (soil moisture depletion)

<table>
<thead>
<tr>
<th>Irrigation Treatment</th>
<th>Season 1 (1989)</th>
<th>Season 2 (1990)</th>
<th>Season 3 (1991)</th>
<th>WUE (kg/m²/ha)</th>
<th>% Seasonal ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPK</td>
<td>393</td>
<td>345</td>
<td>316</td>
<td>0.33</td>
<td>96</td>
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<tr>
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<td>328</td>
<td>290</td>
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<tr>
<td>SMD</td>
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<td>264</td>
<td>249</td>
<td>0.42</td>
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<tr>
<td>Seasonal ET</td>
<td>363</td>
<td>414</td>
<td>359</td>
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</table>

Impact of Irrigation Regimes on Yield of Tomato

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Irrigation Treatment</th>
<th>2004 Total Yield (kg/ha)</th>
<th>2006 Total Yield (kg/ha)</th>
<th>2007 Total Yield (kg/ha)</th>
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<tr>
<td>Ranger</td>
<td>Full ET</td>
<td>87.8</td>
<td>84.5</td>
<td>88.5</td>
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<tr>
<td></td>
<td>DI</td>
<td>63.5</td>
<td>78.5</td>
<td>82.5</td>
</tr>
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Deficit Irrigation: Potatoes

- DI of 24% 17% and 14% Full ET replacement
- Resulted in yield reductions (esp. in larger tuber size)
- Increased N content in DI
  - Increased leaching
  - Increased concentration

Phenological Stage of Growth: Flowering

- Most crops are very sensitive to water stress during bloom
- Pollination – compressed bloom time
- Reduced fertilization – reduced crop
- Perennial Crops – bud initiation for next year

<table>
<thead>
<tr>
<th>Common Bean</th>
<th>Growth Stage (Water Stress Timing)</th>
<th>Mean Yield (kg/ha)</th>
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<tr>
<td>Normal</td>
<td>3.1 a</td>
<td></td>
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<tr>
<td>2 wks after emergence</td>
<td>2.6 b</td>
<td></td>
</tr>
<tr>
<td>4 wks after emergence</td>
<td>2.6 c</td>
<td></td>
</tr>
<tr>
<td>Flowering</td>
<td>2.6 c</td>
<td></td>
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Tomato

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Impact of Irrigation Regimes on Yield of Tomato

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Common Bean

- Growth Stage (Water Stress Timing) | Mean Yield (kg/ha) |
- Normal (no stress) | 3.1 a |
- 2 wks after emergence | 2.6 b |
- 4 wks after emergence | 2.6 c |
- Flowering | 2.6 c |
- 2 wks after flowering | 2.6 c |
Plant Water Stress - Dr. Rebecca Harbut (KPU)

Phenological Stage of Growth: Late Season

- Fruit enlargement/filling
- Reduced yield
- Increased °Brix
- Perennial Crops - think about next season!

Estimating Crop Water Use: ET

- Evapotranspiration
  - Plant transpiration + Soil Evaporation
- Effective Precipitation
  - Water that will enter the soil profile and be available plants
- All the factors that impact VDP impact ET...several variables to account for
- ET calculators are based on an equation, not in-field measurements

Crop Coefficients

- Based on field studies to provide an estimate of ET for specific crops
- Reference crop will typically be used when reporting ET
- \( ETc = ETo \times Kc \)
- \( Kc \) is made of soil evaporation and crop transpiration – changes of the course of the season

Summary

- Water is important!
- Crop response to water is dynamic
  - Varies by crop type, conditions and phenology
- Optimal water supply is not necessarily 'full' water supply
- Timing of water management is critical
- Critical to understand your soils, have the data and know how to respond to it
- Probably lots of room for improvement in water use efficiency