Rebecca Harbut, KPU
Small Farms Workshop, February 13, 2016
KPU, Richmond

Water Stress

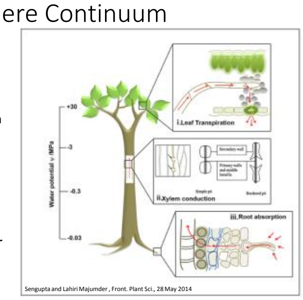
- Drought stress is the most significant environmental stress resulting in crop loss
- 'Agricultural Drought' – lack of adequate moisture for crops to complete normal plant development and crop maturity
  - Meteorological drought – prolonged lack of precipitation
  - Increased evapotranspiration rates

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

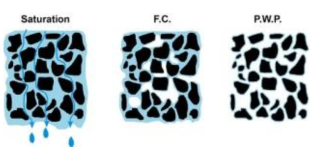
- There is a continuous water column
  - Soil-Plant-Atmosphere
  - Root uptake is junction between soil-plant
    - Root health, depth, growth
  - Evapotranspiration is the junction between plant-atmosphere
    - Stomatal conductance is the 'valve'
- Column is under constant tension
- The water status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



Sengupta and Lahiri Majumder, Front. Plant Sci., 28 May 2014

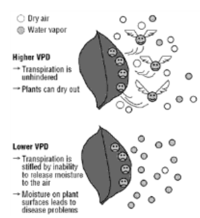
Soil: Plant Available Water

- 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!

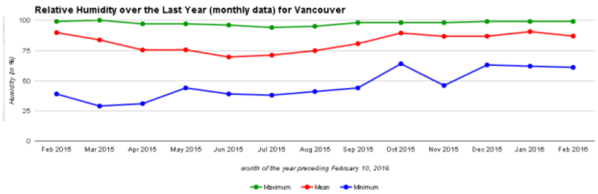


Leaf Vapour Pressure Deficit

- 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



OSU AEX-804-01

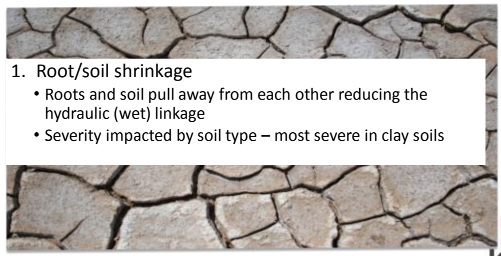


Leaf RH 99.6%, Air RH 96% @ 20^0C
VPD = 5MPa (725 PSI)

On a drier day: Air RH 50% @ 20^0C
VPD = 93 Mpa (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…

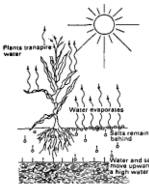


1. Root/soil shrinkage
   - Roots and soil pull away from each other reducing the hydraulic (wet) linkage
   - Severity impacted by soil type – most severe in clay soils

4 Factors that reduce hydraulic conductivity…

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

Nair, It could be salty ou there, 2013



FAO, Irrigation & water management http://www.fao.org/

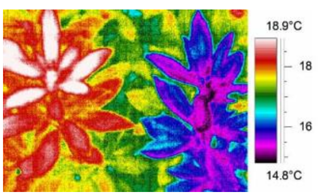
4 Factors that reduce hydraulic conductivity…

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

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

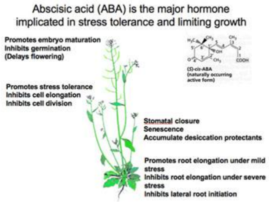
- Transpiration is the cooling mechanism for plants
- Plant and Fruit temperature quickly rises in water stress conditions



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

Abcsisic Acid (ABA) – Stress Hormone

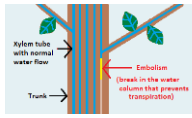
- Water stress increases production of ABA
- Produced in roots
- Reduces stomatal conductance
- Drought stress will trigger signal to shorten crop growth cycle



https://labs.mcdb.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

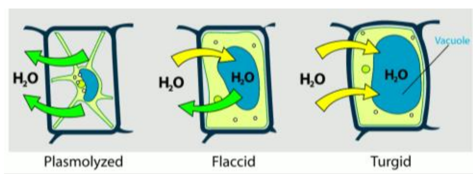
- Factors that influence the impact of water stress:
  - Duration and intensity of water stress
  - Crop phenology
  - Crop genotype

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

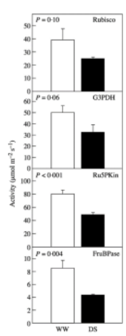
Loss of Turgor Pressure

- Wilting
- Plasma membrane pulls away from cell wall



Water Vs. Carbon

- Water and CO_2 exchange are linked – water conservation = reduced C uptake
- carbon uptake is critical for growth



M. M. CHAVES et al. Ann Bot 2002;89:907-916

Timing is Everything…

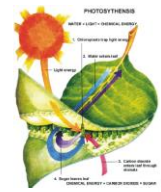
- Phenological stages differ in their sensitivity to water stress
  - Many annual crops are most sensitive to water stress during and immediately after flowering
    - Reduced pollen viability
    - Death of flowering

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

Phenological Stages of Growth: Vegetative Growth

- Vegetative Growth
  - Reduced leaf area index (leaf area/m^2 ground)
  - Early leaf senescence
  - Limits assimilatory power of the plant



Tomato Drip Irrigation

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

Table 2. Irrigation amount and water-use efficiency (WUE) for 1989–91 as influenced by irrigation regime in tomato fruit production.

Irrigation regime[x]	Total water[z] (mm) 1989	1990	1991	WUE[y] ($t \cdot ha^{-1} \cdot mm^{-1}$)	% Seasonal ET_o[w]
EPK	307	345	318	0.33	86
ECC	249	328	290	0.36	76
SMD	216	264	249	0.42	64
Seasonal ET_o	363	414	356		

HORTSCIENCE 28(1):35-37. 1993

Impact of Irrigation Regimes on Yield of Tomato

Table 1. Influence of irrigation regime on tomato fruit yield and size distribution.

Season	Irrigation regime[z]	Fruit yield (kg/plot) Total	Marketable	Cull	Fruit size (%)[y] Large	Medium
1989	EPK	96.2	75.3	20.9	58 ab	42
	ECC	88.1	70.0	18.1	64 a	36
	SMD	94.2	74.5	19.7	55 b	45
		NS	NS	NS		NS
1990	EPK	148 a	132 a	16.1	73	27
	EPK (daily)	155 a	137 a	18.4	72	28
	ECC	155 a	136 a	18.1	68	32
	SMD	131 b	112 b	19.5	68	32
				NS	NS	NS
1991	EPK	183 a	164 a	18.4 a	82	18
	EPK (daily)	169 ab	148 ab	20.5 a	86	14
	EPK × 1.25	154 b	137 b	16.8 ab	82	18
	ECC	163 ab	150 ab	13.6 b	80	20
	SMD	169 ab	163 a	6.4 c	81	19
					NS	NS

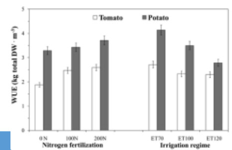
HORTSCIENCE 28(1):35-37. 1993

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

Cultivar	Irrigation Treatment	2004	Total Yield 2006	2007
Ranger Russet	Full ET	87.8	84.5	88.5
	DI	63.5	78.5	82.5

A. K. Alva, A. D. Moore & H. P. Collins (2012), J of Crop Improvement, 26:2, 211-227

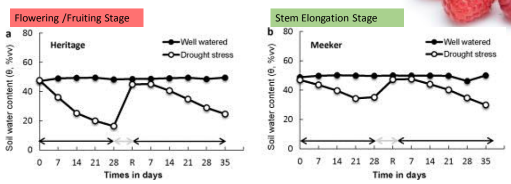


Dalla Costa, L., Giovanardi, R. (2000) Proc. COST 814 Final Conf. pp 443–447, May 2000.

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

Common Bean Growth Stage (Water Stress Timing)	Mean Yield (t/ha)
Normal (no stress)	3.1 a
2 wks after emergence	2.6 b
4 wks after emergence	2.6 b
Flowering	1.8 c
2 wks after flowering	1.9 c



Volumetric soil water content (θ, % v/v) in two raspberry cultivars: Heritage (a) and Meeker (b). During watering experiments, plants were grown in pots under greenhouse conditions (25 °C ± 3, 16/8 h day/night photoperiod) and two watering treatments. C.G. Morales, M.T. Pino, A. del Pozo (2013), Scientia Horticulturae, Volume 162, 2013, 234–241

Phenological Stage of Growth: Late Season

- Fruit enlargement/filling
- Reduced yield
- Increased ^{0}Brix
- Perennial Crops - think about next season!

Estimating Crop Water Use:ET

- Evapotraspiration
  - 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

FARMWEST.COM

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 x Kc
- Kc is made of soil evaporation and crop transpiration – changes of the course of the season

Farm West: Crop Coefficients

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