Don’t Get Burned: Managing salts in greenhouse production

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Outline

- Where do salts come from?
- General salt stress
  - – Symptoms
  - – Cultural Practices that cause High Salts
  - – Sensitive Crops
  - – Guidelines and Management Options
- Managing specific salt ions
  - – Na, Cl, B, (H)CO_3, NH_4, F
- Nutrient Antagonisms

What are salts?

- Compounds that dissolve in water →

ANIONS (-)	CATIONS (+)
Chloride (Cl)	Ammonium (NH_4)
Nitrate (NO_3^-)	Calcium (Ca)
Sulfate (SO_4^-)	Iron (Fe)
	Magnesium (Mg)
	Sodium (Na)
	Potassium (K)

How are salts measured?

- Electrical conductivity (EC)
  - units: 1 dS/m = 1 mS/cm = 1 mhos/cm = 1000 µS/cm
  - old units: 1 mhos
    - luckily, 1 mhos = 1 Siemen (S)
- PPM
  - conversion depends on the specific salts you are using
  - average of all salts: 670 ppm ≈ 1 dS/m
- moles/milliequivalents (SI units)
  - ion specific conversion
    - (40 ppm Ca = 1 mM = 2 meq)

Where do salts come from?

- Container media, example ECs (these vary by source)

Substrate	EC (dS/m)
Compost (Dairy)	7-20
Peat	1.1
Sand	0.2
Soil (Mardin)	1.3
Vermicompost	1.3
Vermiculite	0.1

Where do salts come from?

- Water source
  - salt deposits , limestone, sea-water incursion, road salt

    Target: 0.2-0.75 dS/m

    Acceptable: 0-1.5 dS/m

Massachusetts study of several greenhoues water sources (Cox, Lopes, Smith)

	Municipal	Well (dS/m)
Min	0.05	0.10
Avg	0.39	0.52
Max	3.14	7.15

Where do salts come from?

- Added fertilizer

Concentration (ppm)			Injector Ratios*					Electrical Conductivity (E.C.)**
N	Ca	Mg	1:15	1:100	1:128	1:200	1:300	mmhos/cm
25	8.3	3.3	0.34	2.25	2.88	4.50	6.75	0.17
50	16.7	6.7	0.68	4.50	5.76	9.00	13.50	0.33
75	25	10.0	1.00	6.75	8.64	13.50	20.25	0.50
100	33.3	13.3	1.35	9.00	11.52	18.00	27.00	0.66
150	50	20.0	2.03	13.50	17.28	27.00	40.50	0.99
200	66.7	26.7	2.70	18.00	23.04	36.00	***	1.32
300	100	40.0	4.05	27.00	34.56	***	***	1.98
400	133.3	53.4	5.40	36.00	46.08	***	***	2.64

- Example from 15-5-15 Cal Mag fertilizer:
  - when applied at 200 ppm N, the water will contain an additional 1.32 dS/m of salinity

Salt Stress

- Osmotic effects
  - loss of osmotic gradient for water absorption
  - → wilting (even though substrate is moist)
  - If stress is prolonged may see reduced growth, smaller leaf area, shorter plants (may or may not see wilting)
- Toxic concentrations of ions
  - excess absorption of Na, Cl
  - excess absorption of micronutrients (B, Mn, Fe, F)
- (Bi)carbonate
  - high pH
  - precipitation of Ca/Mg increasing sodicity
- Nutrient antagonisms
  - an excess of one nutrient limits absorption of another

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General high salt levels

- Osmotic stress
  - Wilting

Note accumulated salts on the surface

General high salt levels

- Osmotic stress
  - Smaller leaf and flower size

Control

+3500 ppm Cl
+2300 ppm Na

Osmotic Stress - Shorter Stems

50	100	200	350	500 ppm N
0.9	1.2	2.1	3.9	6.2 dS/m

Source: Neil Mattson

Symptoms of Excess Soluble Salts

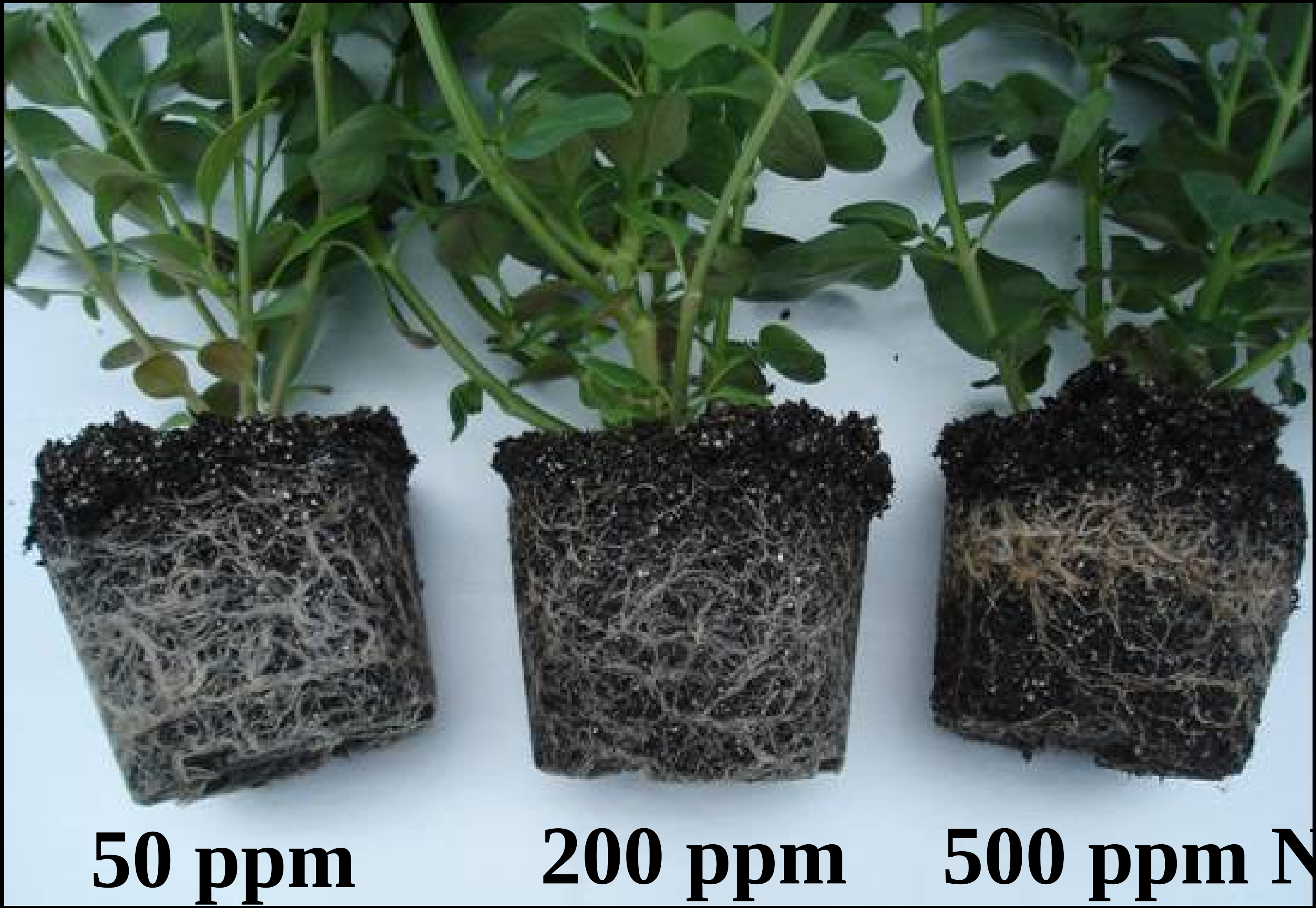
- marginal chlorosis → necrosis of older leaves

Symptoms of Excess Soluble Salts

- Death of root tips
- Increased *Pythium* susceptibility

Cultural Practices that Cause High Salts

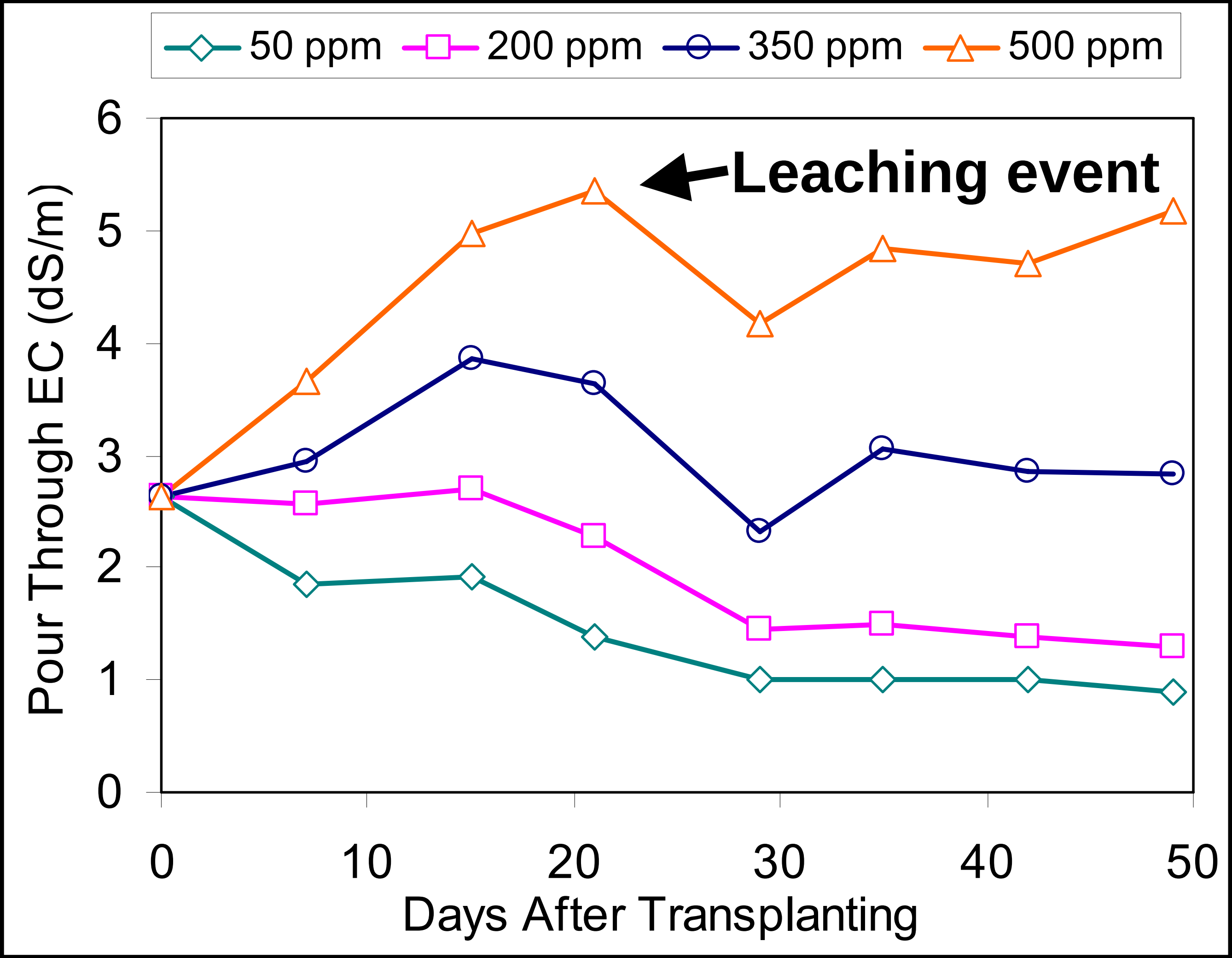
Snapdragon subirrigated with a complete fertilizer
Note poor root growth in 500 ppm treatment



Source: Neil Mattson

Cultural Practices that Cause High Salts

Liquid feed at varying concentrations

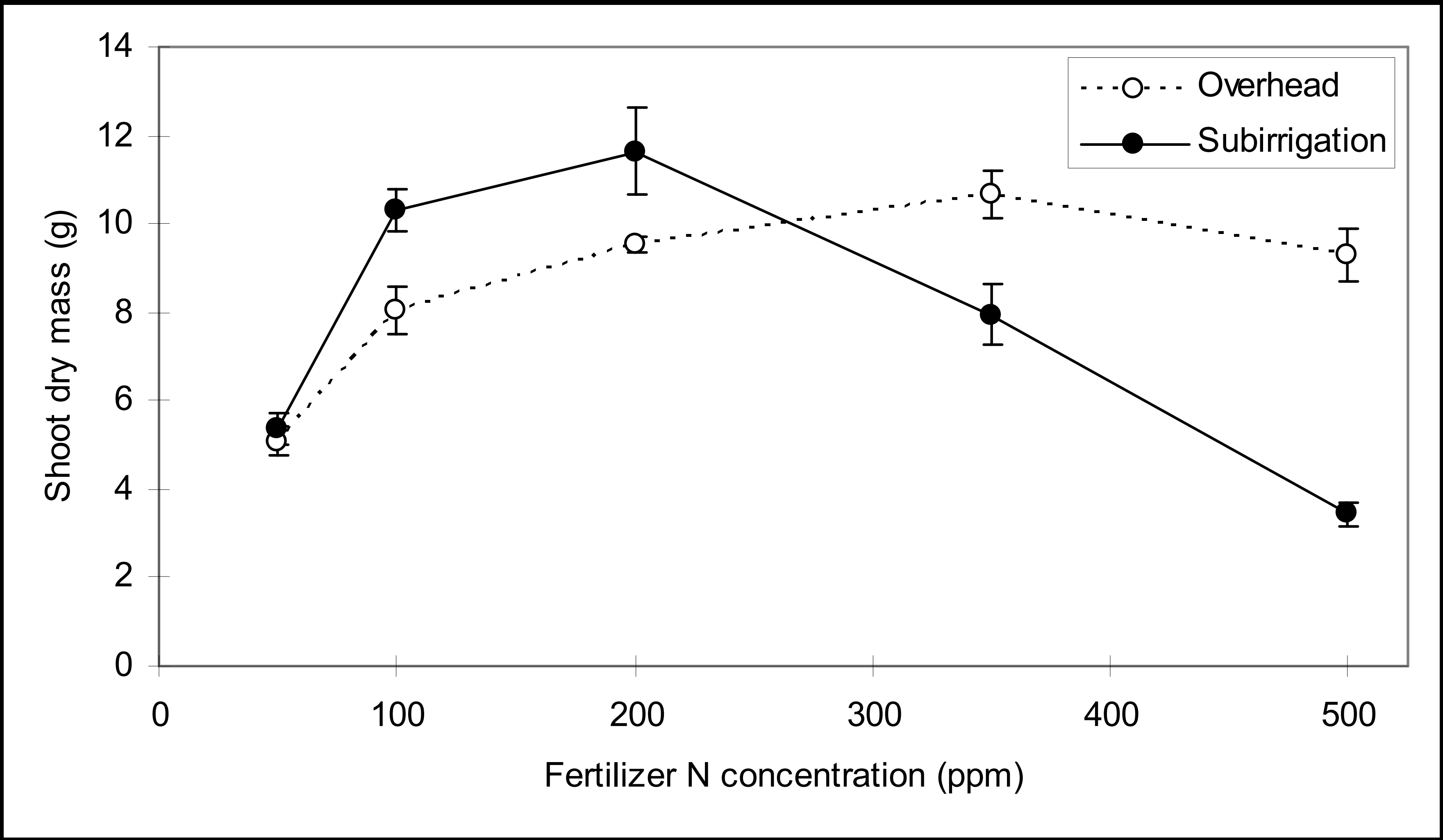


Source: Neil Mattson

Cultural Practices that Cause High Salts

Effect of irrigation method and fertilizer concentration

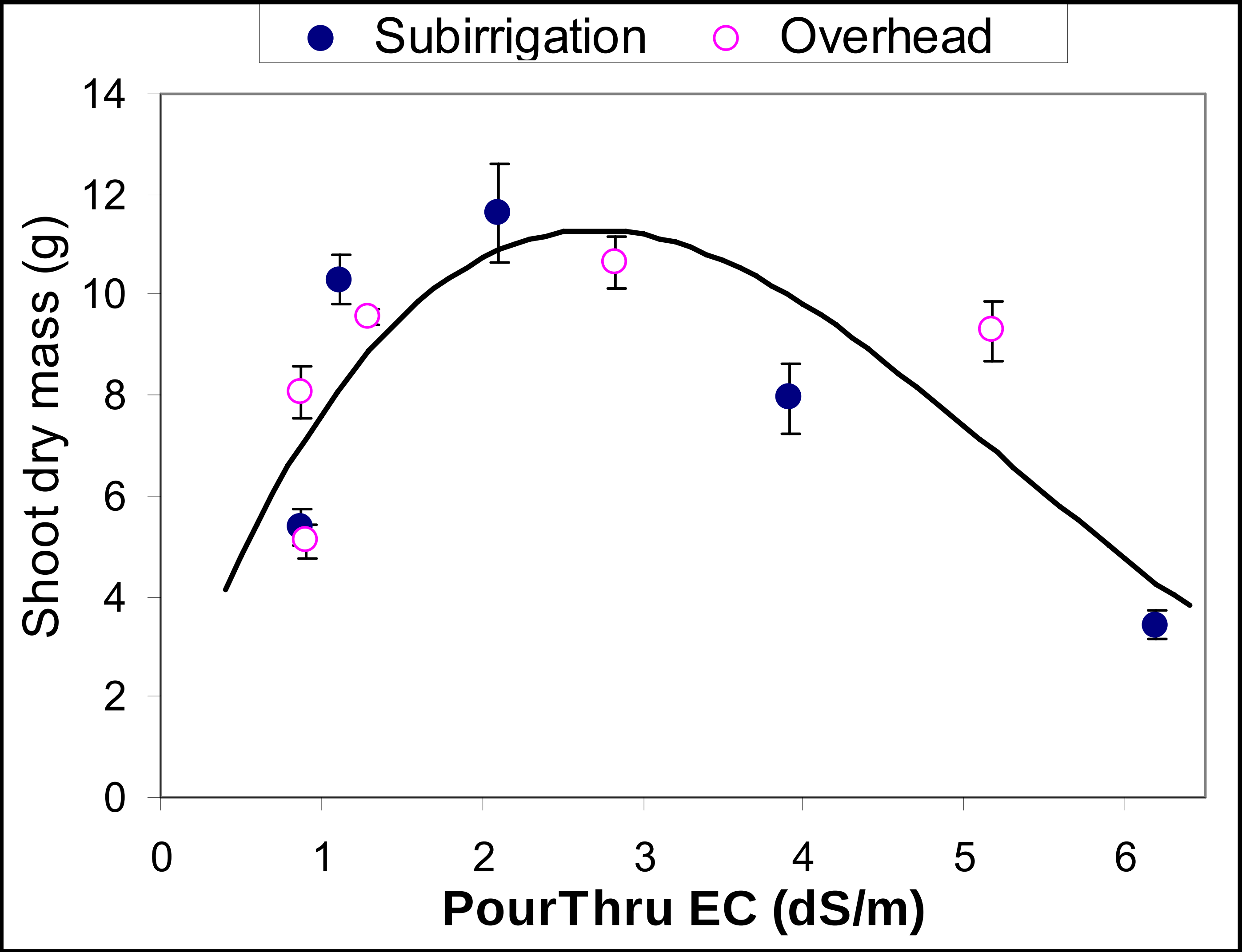
Impatiens 'Super Elfin Mix'



Source: Neil Mattson

Cultural Practices that Cause High Salts

Fertility and Substrate EC Affects Growth
Impatiens 'Super Elfin Mix'



Source:
Neil Mattson

Cultural Practices that Cause High Salts

Fertility and Substrate EC Affects Growth

Impatiens 'Super Elfin Mix'

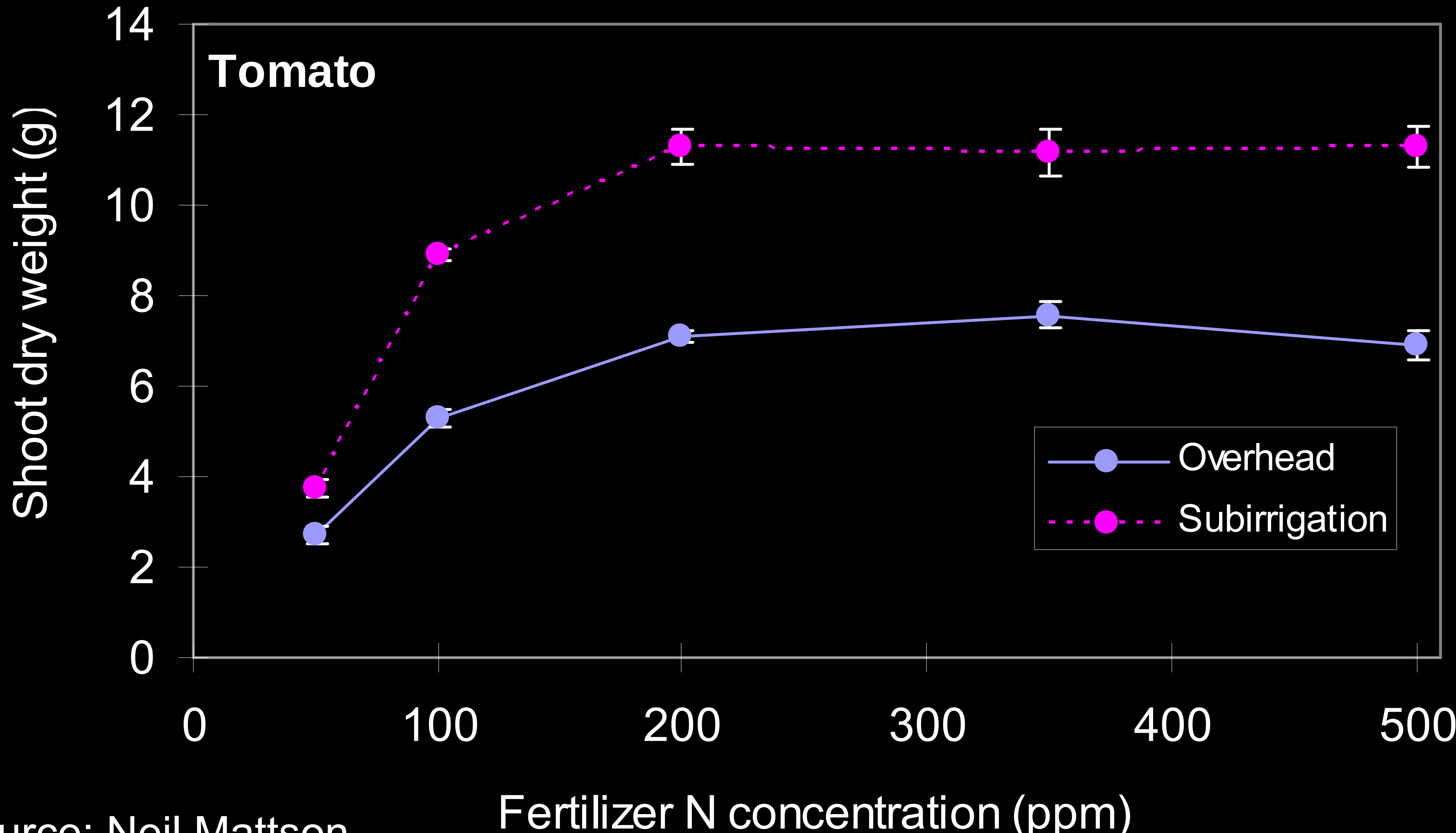
50	100	200	350	500 ppm N
0.9	1.2	2.1	3.9	6.2 dS/m

Subirrigation

Source: Neil Mattson

Cultural Practices that Cause High Salts

- Tomato 'Sweet 100' grown for 4 weeks at different fertility levels, was tolerant of salts to 500 ppm N



Source: Neil Mattson

Cultural Practices that Cause High Salts

- High Salts from Over Fertilization, caused by
  - overwatering
  - poor drainage
  - root rots

High EC from over watering

Photos: Douglas Cox, UMass

High Salts from CRF

- Use media within 1 week after incorporating CRFs

- Carefully measure rate during mixing – difficult to correct high salts

Photo: Peter Davies, Cornell University

Sensitive Bedding/Potted Plants

- Calceolaria
- Celosia
- Fibrous begonia
- Impatiens
- Pansy
- Zinnia

Herbaceous Annuals

- *Agastache cana*
- *Echinacea purpurea*
- *Leucanthemum* x *superbum 'Alaska'*
- *Sedum Acre*

EC Guidelines

Table 3. EC interpretation values (mS/cm) for various extraction methods[1].

1 : 5	1 : 2	SME	PourThru[2]	Indication
0 to 0.11	0 to 0.25	0 to 0.75	0 to 1.0	**Very Low.** Nutrient levels may not be sufficient to sustain rapid growth.
0.12 to 0.35	0.26 to 0.75	0.76 to 2.0	1.0 to 2.6	**Low.** Suitable for seedlings, bedding plants and salt sensitive plants.
0.36 to 0.65	0.76 to 1.25	2.0 to 3.5	2.6 to 4.6	**Normal.** Standard root zone range for most established plants. Upper range for salt sensitive plants.
0.66 to 0.89	1.26 to 1.75	3.5 to 5.0	4.6 to 6.5	**High.** Reduced vigor and growth may result, particularly during hot weather.
0.9 to 1.10	1.76 to 2.25	5.0 to 6.0	6.6 to 7.8	**Very High.** May result in salt injury due to reduced water uptake. Reduced growth rates likely. Symptoms include marginal leaf burn and wilting.
>1.1	>2.25	>6.0	>7.8	**Extreme.** Most crops will suffer salt injury at these levels. Immediate leaching required.

[1]Adapted from: On-site testing of growing media and irrigation water. 1996. British Columbia Ministry of Agriculture.
[2]Due to the variability of the PourThru technique results, growers should always compare their results to the SME method to establish acceptable ranges.

Source: Todd Cavins et al., NCSU, http://www.pourthruinfo.com/

EC Guidelines

Table 2. The relative nutrient requirements of actively growing greenhouse crops, with EC ranges for both the SME and PourThru methods. Use this classification system and the examples provided in Figure 3 for the PourThru method to determine the suggested target EC ranges for the entire crop production cycle.

No Additional Fertilizer Required
Amaryllis
Crocus
Narcissus

Light (SME EC of 0.76 to 2.0 mS/cm) (PourThru EC of 1.0 to 2.6 mS/cm)	
Aconitum	Coleus
African Violet	Cosmos
Ageratum	Cuttings (during rooting)
Anemone	Cyclamen
Anigozanthos	Freesia
Asclepias	Geranium (seed)
Aster	Gerbera
Astilbe	Gloxinia
Azalea	Impatiens
Balsam	Marigold
Begonia (fibrous)	New Guinea Impatiens
Begonia (Hiemalis)	Orchids
Begonia (Rex)	Pansy
Begonia (Tuberous)	Plugs
Caladium	Primula
Calceolaria	Salvia
Calla Lily	Streptocarpus
Celosia	Snapdragon
Cineraria	Zinnia

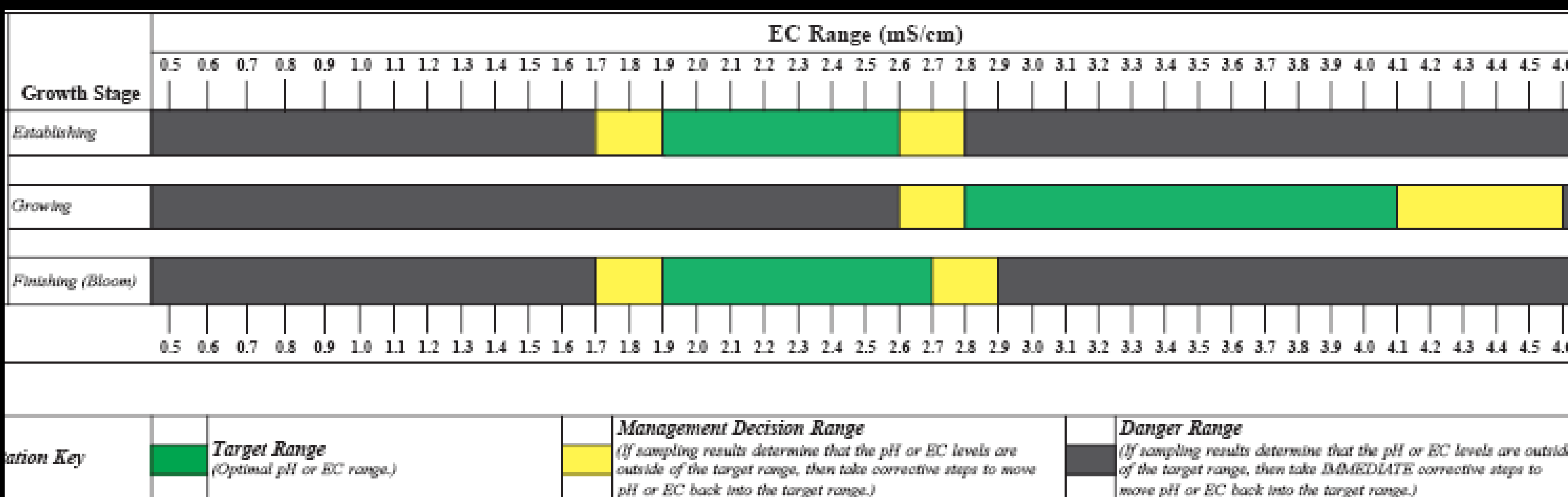
Medium (SME EC of 1.5 to 3.0 mS/cm) (PourThru EC of 2.0 to 3.5 mS/cm)	
Alstroemeria	Kalanchoe
Alyssum	Larkspur
Bougainvillea	Lily, Asiatic & Oriental
Calendula	Lily, Easter
Campanula	Lobelia
Cactus, Christmas	Morning Glory
Carnation	Onion
Cauliflower	Ornamental Kale
Centaurea	Ornamental Pepper
Cleome	Oxalis
Clerodendrum	Pepper
Crossandra	Petunia
Dahlia	Phlox
Dianthus	*Platycodon*
Dusty Miller	Portulaca
Exacum	Ranunculus
Geranium (cutting)	Rose
Hibiscus	Sunflower (potted)
Hydrangea	Tomato
Jerusalem Cherry	Verbena

Heavy (SME EC of 2.0 to 3.5 mS/cm) (Pourthru EC of 2.6 to 4.6 mS/cm)
Chrysanthemum
Poinsettia

Source: Todd Cavins et al., NCSU, http://www.pourthruinfo.com/

Monitoring EC – Pour Thru

- Example for Poinsettia
  - Establishing 1.9 – 2.6 dS/m
  - Active Growth 2.8 – 4.1 dS/m
  - Finishing 1.9 – 2.7 dS/m

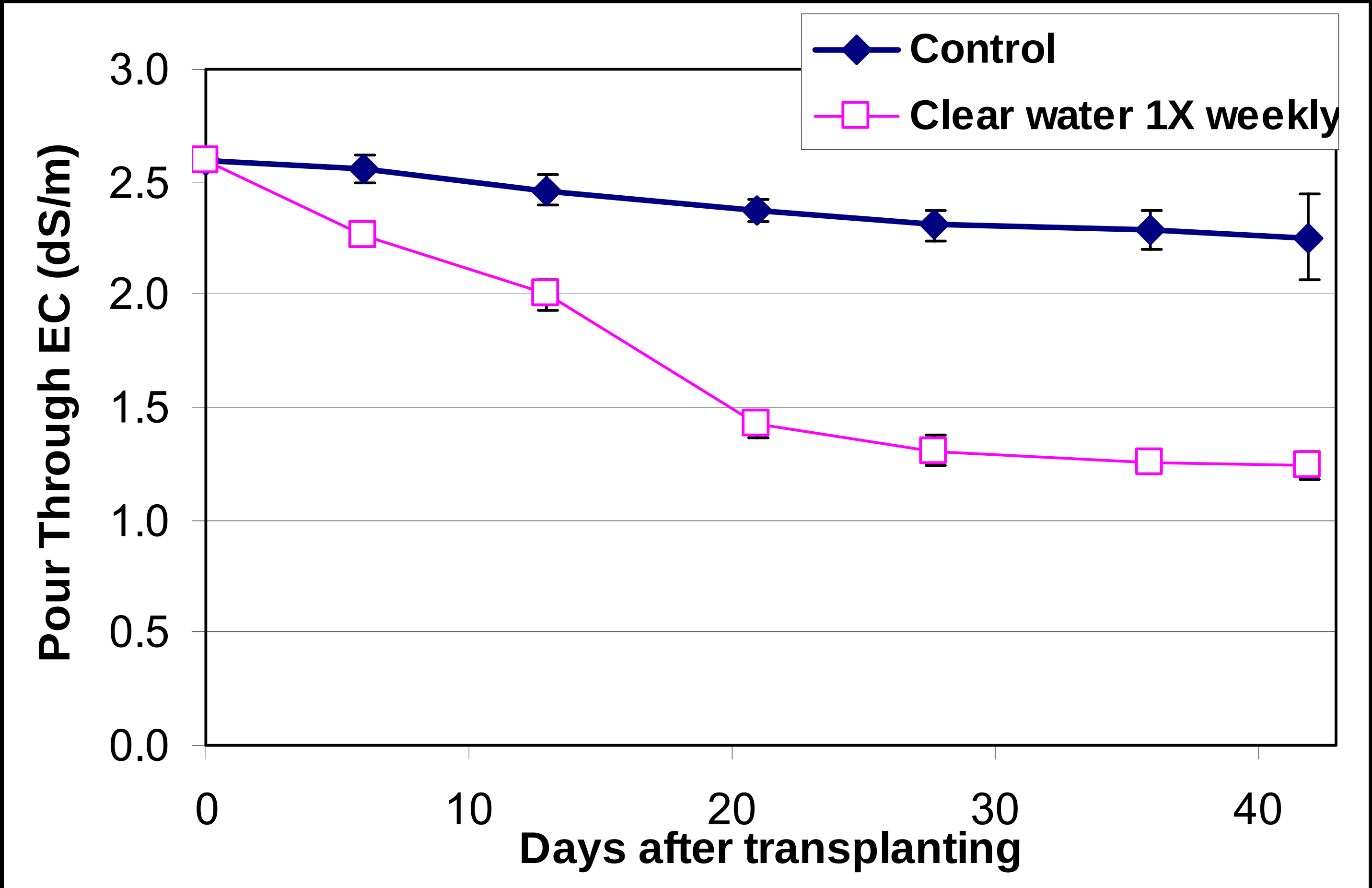


Source: Todd Cavins et al., NCSU, http://www.pourthruinfo.com/

Short Term Management Options

- Leaching

Example: Clear water application 1x / week vs. Control (constant liquid feed)



Long Term Management Options

- Decrease fertility
- Periodic Leach
- A look at fertilizer sources and salt levels → compare labels
- Switch water source?
- (Ebb and flow difficult using poor quality water for sensitive crops)

EC Management Using Leaching

Recommended leaching fraction for container media

EC of Applied Water	Leaching Fraction
> 2 dS/m	30%
> 1.5 dS/m	20%
< 1 dS/m	10%

Young Plants are More Sensitive to Salts

Fertilizer levels by plugs stage

Stage 2	50-75 ppm N	1-2X/week
Stage 3	100-150 ppm N	1-2X/week
Stage 4	100-150 ppm N	1-2X/week

– mostly Nitrate based N

Pour Thru EC: 1.0-2.6

Souce: Styer and Koranski, Plug and Transplant Production, 1997

Young Plants are More Sensitive to Salts

Low Fertility Plugs

Stage 2 < 1.5 dS/m (PourThru)

Stage 3 1.5-2.5 dS/m (PourThru)

Celosia	Eggplant
F. Kale/Cabbage	Lettuce
Pansy	Pepper
Snapdragon	Tomato

Souce: Styer and Koranski, Plug and Transplant Production, 1997

Young Plants are More Sensitive to Salts

Medium Fertility Plugs

Stage 2 2-2.5 dS/m (PourThru)

Stage 3 2.5-3 dS/m (PourThru)

Ageratum	Browallia	Cyclamen
Dianthus	Dusty miller	Impatiens
Lisianthus	Marigold	Primula
Salvia	Verbena	Vinca

Souce: Styer and Koranski, Plug and Transplant Production, 1997

Water Quality Guidelines for Plug Production

pH	5.5-6.5
Alkalinity	60-80 ppm $CaCO_3$
EC	< 0.75 dS/m
Sodium	< 40 ppm
Chloride	< 70 ppm
Sulfates	24-240 ppm OK
Boron	< 0.5 ppm
Fluoride	< 1.0 ppm
Iron	< 5.0 ppm

Adapted from: Styer and Koranski, Plug and Transplant Production, 1997

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Sodium / Chloride Toxicity

- Symptoms
  - Leaf margin/tip chlorosis → necrosis
  - Old leaves affected first
  - Cl typically more toxic
  - Foliar applied Cl > 100 ppm can also cause burn

Photo: Paul Lopes, UMass

Chloride Sensitive Plants

- Roses
- Camellias
- Azaleas
- Rhododendrons

Management Options Chronic Salt Problems

- The case of high NaCl in water supply
  - Be careful of plants drying out
  - Blended water, reverse osmosis
  - Adding enough Ca, K
  - Avoid wetting foliage during irrigation

Boron Toxicity

Symptoms

- Yellowing of leaf tips/margins → brown
- Old leaves affected first

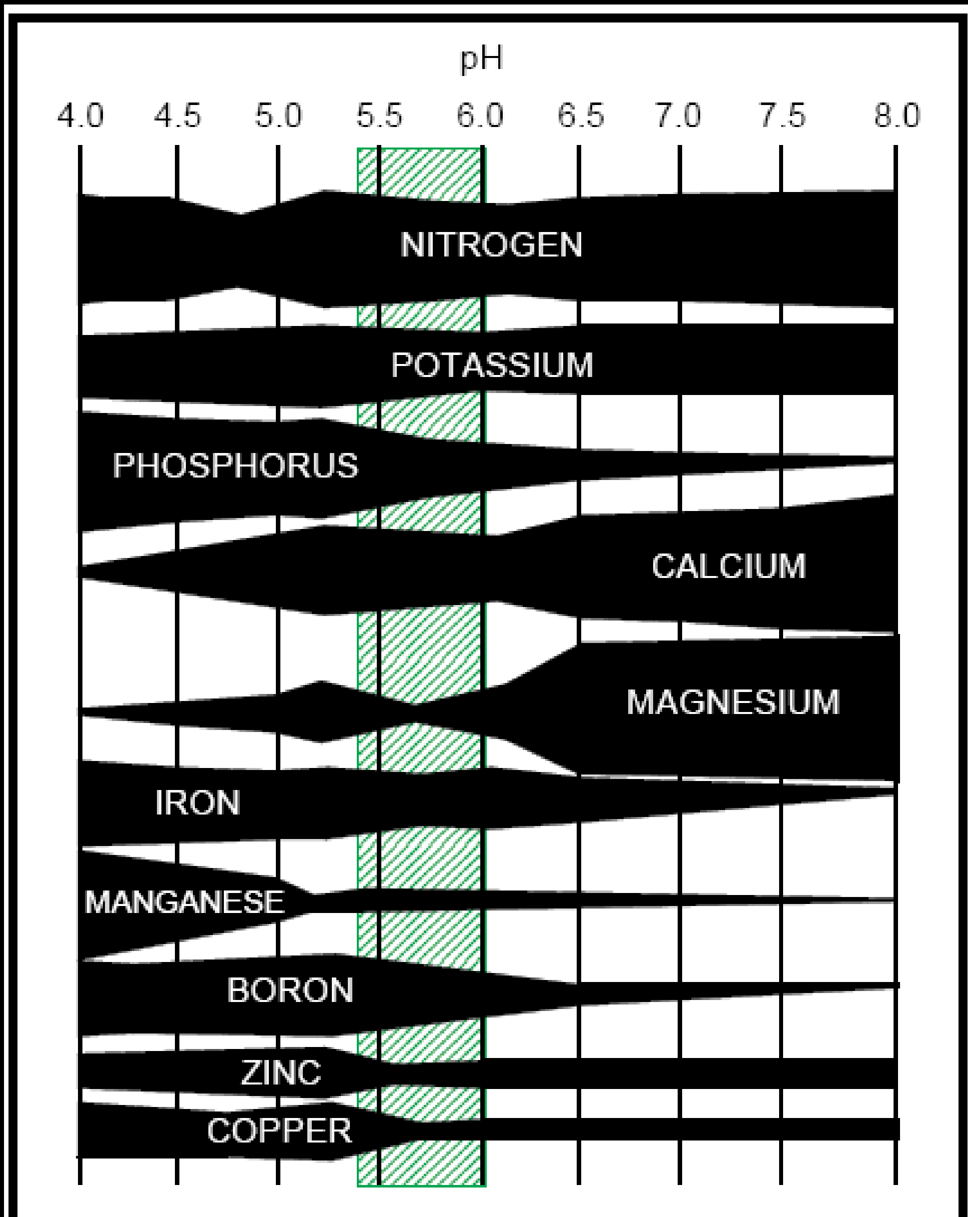
Boron Sensitivity

SENSITIVE SPECIES Threshold of source water 0.5-1.0 ppm B	
Geranium	Larkspur
Pansy	Rosemary
Zinnia	

MODERATELY SENSITIVE Threshold of source water 1.0-2.0 ppm B	
Calendula	Gardenia
Marigold	Poinsettia

Source: Maas, 1986

Boron Sensitivity and pH



- Low pH favors Boron toxicity
- High pH favors Boron deficiency

Graph: Bailey et al., NCSU, http://www.floricultureinfo.com/

Boron Deficiency - Symptoms

- Growing point and new leaves affected
- Hard, distorted, mottled upper foliage
- Abortion of growing point
- Proliferation of branches

Photo: Brian Krug, UNH

Boron Deficiency - Causes

- Petunia/Pansy plugs and flats often affected
- Low B in tap water
- High pH
- High Calcium
- Inactive roots
  - waterlogged
  - cold
  - high humidity

Photo: Brian Krug, UNH

Alkalinity

Alkalinity – the ability of water to neutralize acids

- due to the presence of dissolved alkalis: $Ca(HCO_3)_2$, $NaHCO_3$, $Mg(HCO_3)_2$, $CaCO_3$
- Do not confuse with "Alkaline" which means pH level greater than 7
- Reported in terms of ppm $CaCO_3$ (or meq; 50 ppm = 1 meq $CaCO_3$)
- Typically varies from 50-500 ppm

What is Optimal Alkalinity?

	Optimal	Concern
Plugs	60-100	<40, >120
Flats/Small Pots	80-120	<40, >140
Large containers (> 6 inches)	120-180	<60, >200

Problems with High Alkalinity

- Rapid media pH rise
- Iron/Manganese deficiency
- Ca/Mg can precipate and excacerbate high Na

Problems with Low Alkalinity

- pH of container media will change more rapidly
- Magnesium/Calcium deficiency
- Low pH induced Iron/Manganese Toxicity (photo on right)

Crops Sensitive to High Alkalinity

Iron-inefficient group (Petunia group)

- require a lower pH (5.4-6.0)
  - Bacopa
  - Calibrachoa
  - Diascia
  - Nemesia
  - Pansy
  - Petunia
  - Snapdragon
  - Vinca

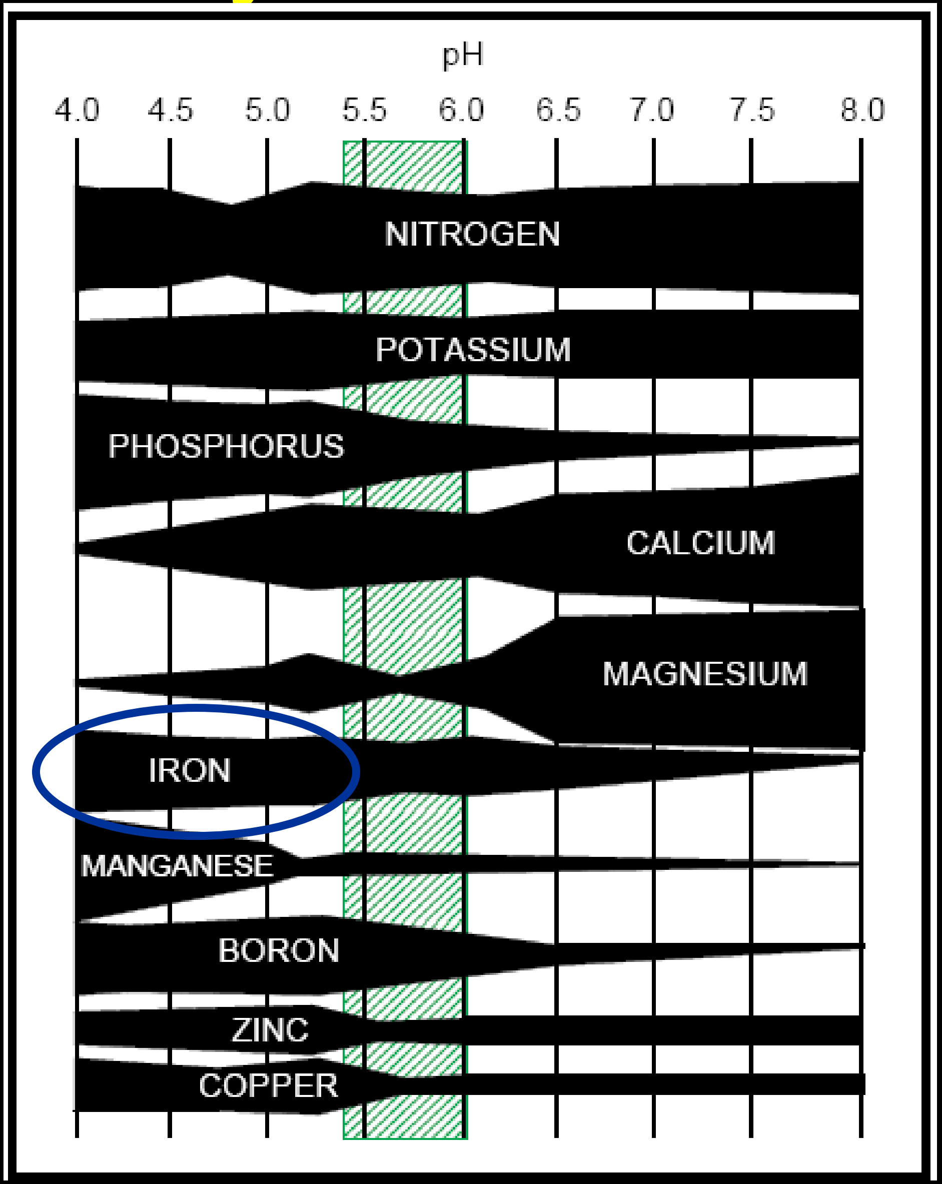
Crops Sensitive to Low Alkalinity

Iron-efficient group (Geranium group)

- Require a higher pH 6.0-6.6
  - Marigold
  - Seed/Zonal Geraniums
  - New Guinea Impatiens
  - Lisianthus

Iron toxicity

- Typically from low pH in container media
- For water sources with high Iron (>3 ppm)
  - removal through flocculation / aeration



Graph: Bailey et al., NCSU, http://www.floricultureinfo.com/

Correcting High Alkalinity

1) Change or blend the water source
   rainwater, pond water
2) Use an acidic fertilizer
3) Inject acid into irrigation water
4) Ensure Iron is available in the root-zone

Factors using fertilizer to adjust pH

- Fertilizer approach does not work well in dark/cool weather
  - In dark/cool weather plants accumulate ammonium (toxicity)
  - ammonium in the medium does not convert to nitrate (so there is less pH effect)
- Sometimes ammonium will not drop pH due to high lime in container media, or high water alkalinity (>300 ppm)

Acid Injection

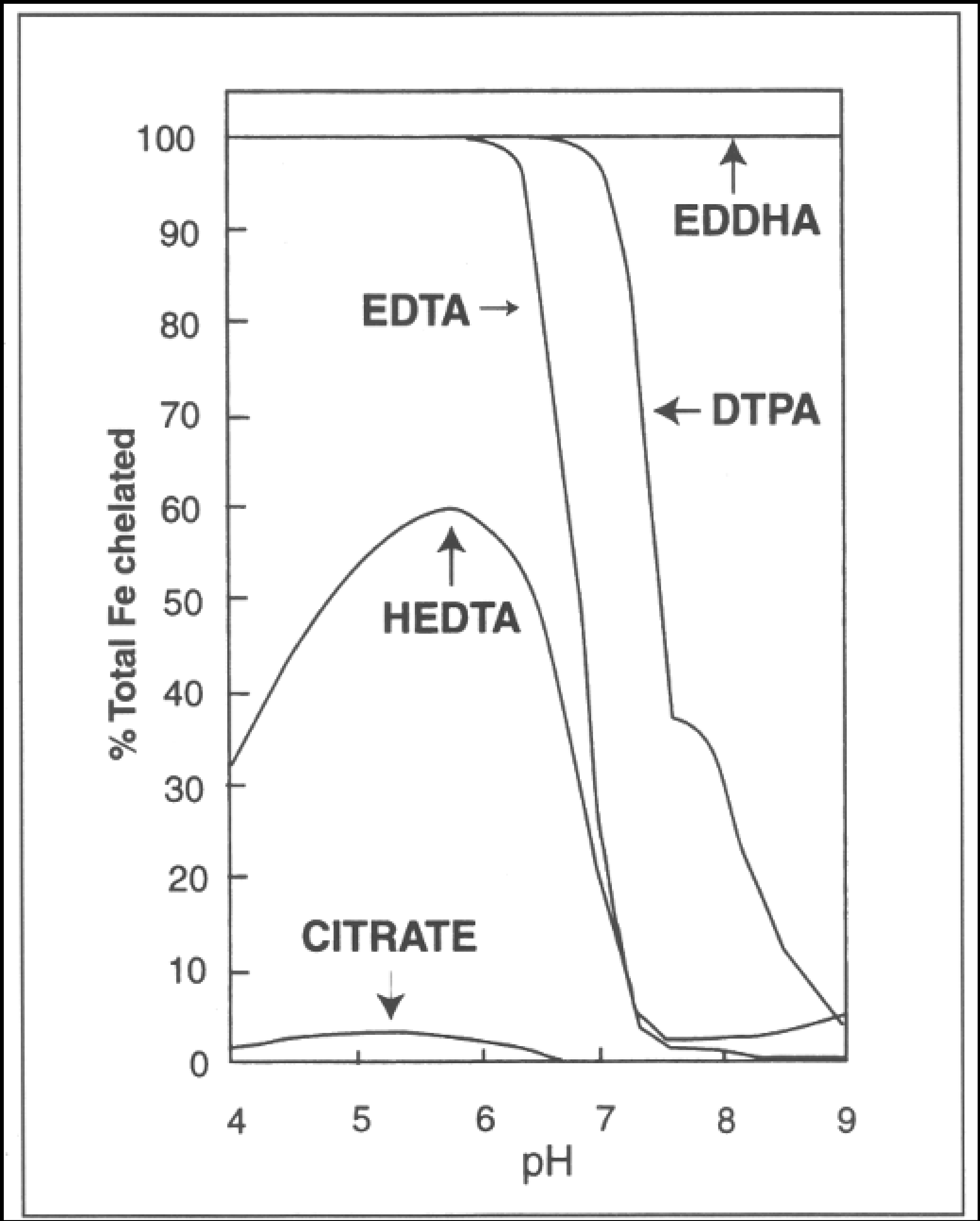
Acidification reduces the amount of carbonates and bicarbonates

H^+ (from acid) + HCO_3^- (in water) → $CO_2 + H_2O$

Which Acid to Use?

- Safety
  - Nitric acid is very caustic and has harmful fumes
  - Sulfuric, Phosphoric, Citric relatively safe
- Cost
  - Sulfuric is cheapest, others are 2-4 times more expensive
- Nutrients from Acid
  - Sulfuric provides S
  - Nitric provides N
  - Phosphoric provides P (but can be too much if equilibrating >100 ppm alkalinity

Solubility of Various Iron Forms



Source: Reed, Water, Media, and Nutrition, 1996

Iron Chelate Products

Iron Form	% Iron	Product
Iron EDTA	13%	Sequestrene Fe Dissolzine EFe13
Iron DTPA	10-11%	Sequestrene 330 Sprint 330 Dissolzine DFe11
Iron EDDHA	6%	Sequesterene 138 Sprint 138 Dissolzine QFe6

- Apply drenches at 5 oz/100 gal
- Foliar sprays at 60 ppm Fe (6-8 oz/100 gal)

Phytotoxicity and Foliar Iron Sprays

Wash foliage with clear water soon after applying iron chelate

Ammonium Toxicity

Symptoms:
Chlorosis/necrosis of leaf margins and between veins

Thick/leathery leaves
Death of root tips

Photos: Cari Peters

Causes of Ammonium Toxicity

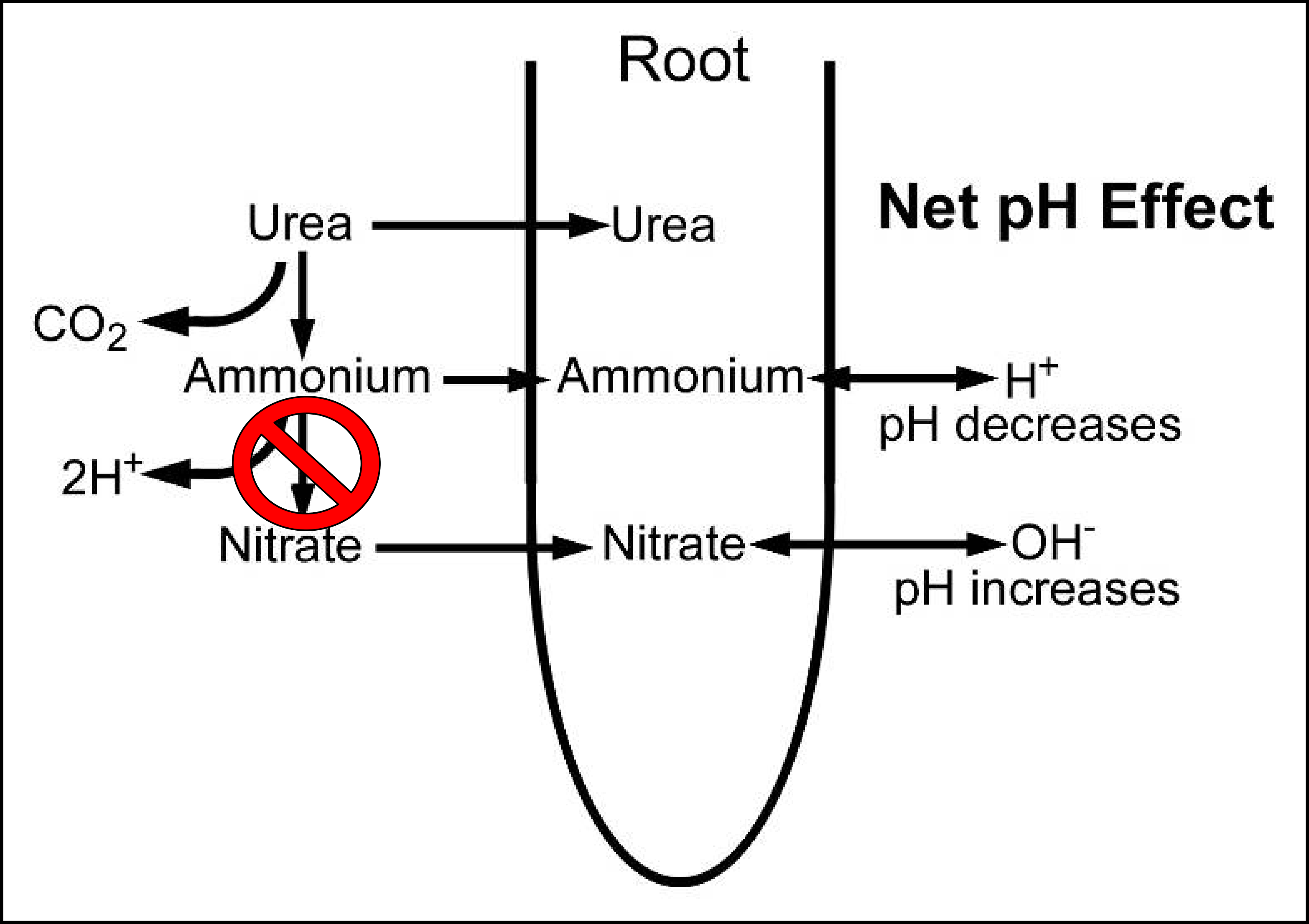
- High amount in fertilizer
- Use of immature manure/compost
- Cool/wet soils inhibits conversion of Ammonium → Nitrate
- Low pH (<5.5) inhibits conversion
- and ammonium does not readily leach from most substrates

Crops Sensitive to Ammonium Toxicity

- Coleus
- Cosmos
- Geranium (*Pelargonium*)
- Salvia
- Zinnia
- Tomato
- Eggplant
- Pepper

Photo: Margery Daughtrey

Ammonium accumulates when nitrification is inhibited



Solving Ammonium Toxicity

- Maintain Root temps ≥ 60 F
- Use ≤ 40% of Nitrogen ammonium
- Discontinue current fertilizer → switch to nitrate until conditions improve

Ammonium does not readily leach, but in a pinch…

- Top-dress gypsum - 1 tablespoon per 6” pot
- water in with clear water
- drench with 50 ppm calcium nitrate after 2 hrs

Fluoride Toxicity

- Symptoms
  - chlorosis of leaf tips/margins, followed by necrosis
  - lower leaves affected first
- Sources
  - municipal waters (>1 ppm F)
  - superphosphate (1600 – 2600 ppm)
- Susceptible plants:
  - Easter Lily, Gladiolus
  - Many foliage plants that are monocots
- Solutions
  - substitute monocalcium-phosphate
  - maintain higher pH

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Nutrient Antagonisms

- Occurs when one nutrient is present in excess, and limits root absorption of another nutrient

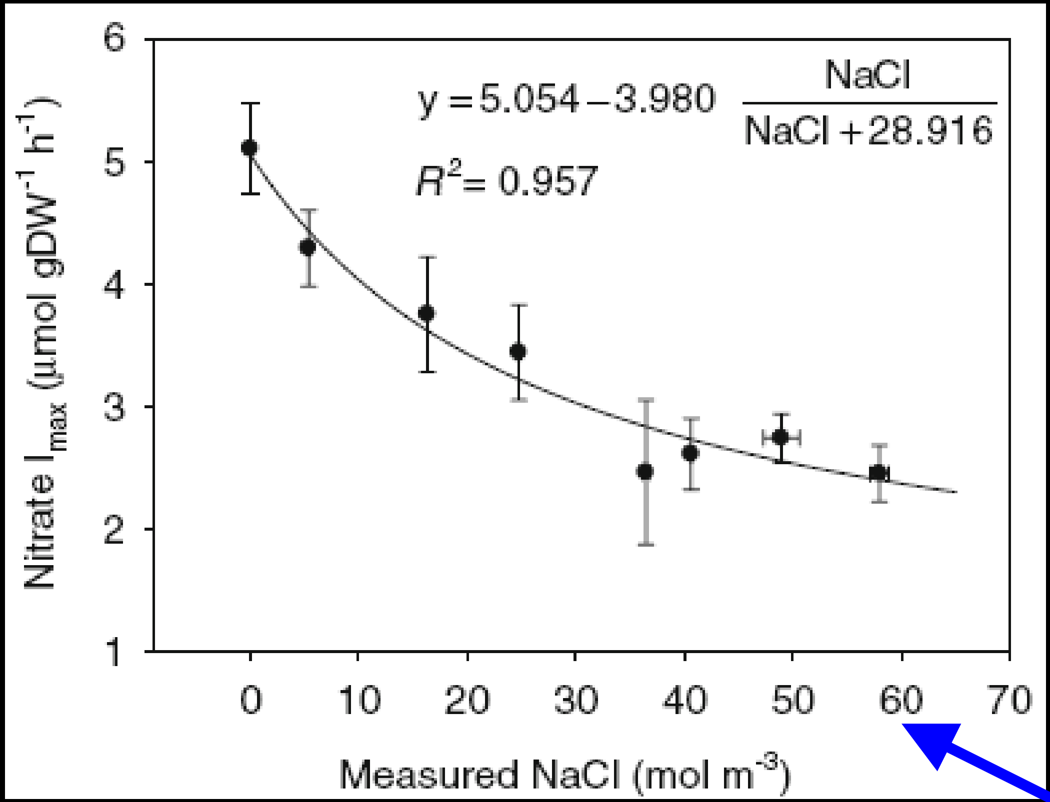
Excessive in Media →	Low Tissue Level
NH_4, Na, K, Ca, Mg	Na, K, Ca, or Mg
PO_4	Zn or Fe
Ca	B
Cl	NO_3

Source: Paul Nelson

Nutrient Antagonisms

Ex: Chloride inhibits nitrate uptake in roses

Rate of nitrate uptake by roots



1400 ppm Na
2100 ppm Cl

Source: Massa, Mattson, and Lieth, 2008

Questions? Neil Mattson nsm47@cornell.edu

Online: http://www.greenhouse.cornell.edu

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