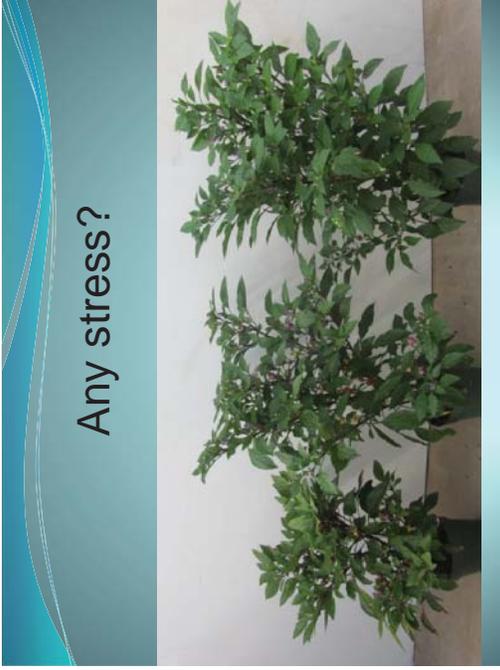


Salt Tolerant Plants for Earth Kind Landscapes

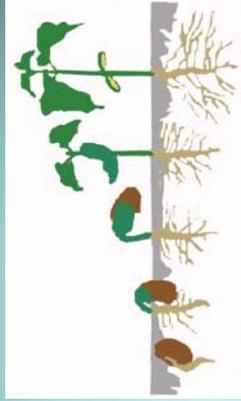
Genhua Niu
Texas A&M University
AgrLife Research at El Paso



Any stress?

Five essential conditions for plant growth:

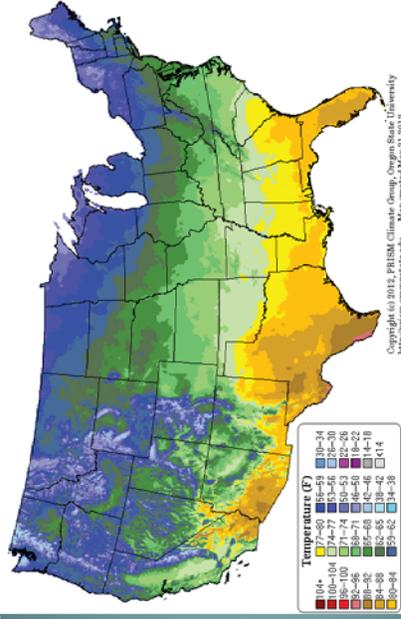
- Light
- Temperature
- CO₂
- Water
- Nutrients



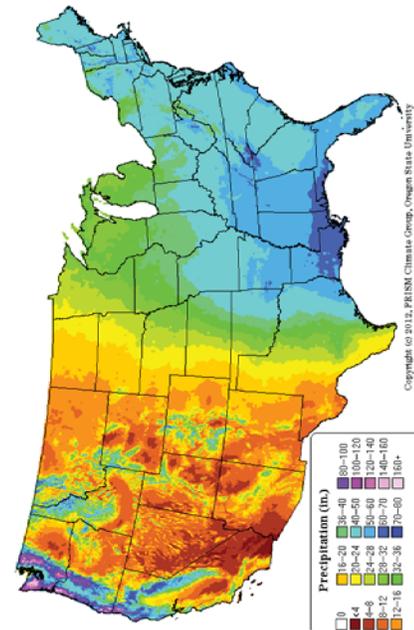
Common abiotic stresses

- Temperature (low, high)
- Water (water-logging and drought)
- Salt stress
- Nutrient deficiency
- Chemical (pH, Herbicides, pollutants), etc.

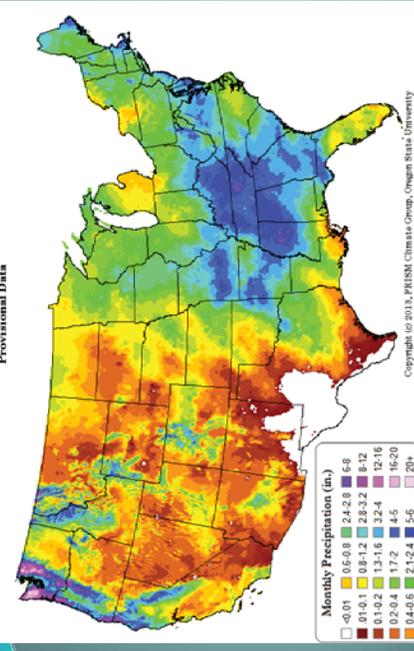
Maximum Temperatures: Apr. 2012
Provisional Data



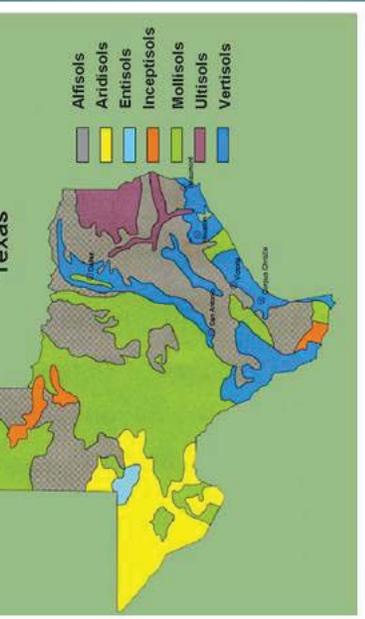
Precipitation: Annual Climatology (1981-2010)



Precipitation: Mar. 2013
Provisional Data



Dominant Soil Orders Texas



Challenges for TX landscapes

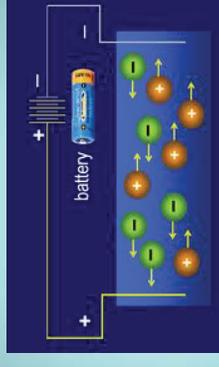
- Wide Climate zones- arid west and humid east.
- High temperatures
- Water quantity – limited water resources, unpredictable drought, etc.
- **Poor water quality and high soil salinity**
 - use of alternative water sources such as municipal reclaimed water and brackish ground water for irrigation of landscapes.

What is salinity

- Salinity is the saltiness or the dissolved salt content of water or soil.
- Primary concern of irrigation water quality is salinity level.
- The individual chemical constituents: positively charged K^+ , Ca^{2+} , Mg^{2+} , Na^+ , NH_4^+ , H^+ , negatively charged: Cl^- , HCO_3^- , CO_3^{2-} , NO_3^- , and SO_4^{2-}

Electrical Conductivity

- Positively charged K^+ , Ca^{2+} , Mg^{2+} , Na^+ , NH_4^+ , H^+
- Negatively charged: Cl^- , HCO_3^- , CO_3^{2-} , NO_3^- , and SO_4^{2-}



Measurement (1)

- In agriculture, the overall salinity is the determination of electrical conductivity of a water (EC_w) or soil extract (EC_e) and reporting unit is dS/m or mmhos/cm.
- Percentage (%)
- For individual ion, ppm (mg/L) is also used.



Measurement (2)

- Total dissolved solids (salts) (TDS): ppm (or mg/L)
- Relationship between EC and TDS (roughly, depending on composition):
TDS = EC x 640 (EC < 5 dS/m)
TDS = EC x 800 (EC > 5 dS/m)

Water Salinity

Fresh water	Brackish water	Saline water	Brine
<0.05%	0.05-3%	3-5%	>5%

TDS Meter



pH/EC/TDS meter



Soil Salinity – salt content in soil



Causes for high soil salinity

- Low quality irrigation water
- Low rainfall
- Climate (high temp & wind)
- Sea water intrusion

EC of fresh water and seawater

- Sea water has a EC of 37 to 62 dS/m (30,000 to 50,000 ppm)
- TDS of **fresh water** < 500 ppm (EC < 0.8 dS/m)
- El Paso Reclaimed water EC ranges from 1.3 to 2.0 dS/m, varying with source water. Tap water is 0.8 – 1.1 dS/m



Reclaimed (Recycled) Water

- Treated sewage effluents (secondary or tertiary treatment)
- It has high salt levels (2 to 3 times higher than fresh water), but depends on sources
- Major salts: Sodium Chloride, and some other salts.
- Nutrients: N, P, Mg, Ca, etc.

Water quality ratings

EC (dS/m)	Water salinity rating
<0.65	Low
0.65-1.3	Moderate
1.3-2.9	High
2.9-5.2	Very high
>5.2	Extremely high

Determining soil salinity

- Take soil sample
- Make a saturated paste
- Take the extraction of the paste
- Determine the salinity of the extraction

Benefits of using reclaimed water

- Conserve fresh water
- Reduce peak water use
- Become more drought resistant
- Low cost – (need fewer treatments)
- Plants can serve as a “bio-filtration system” to some extent - Supply nutrients to landscape plants

Soil and water salinity based on plant tolerance

Plant salt tolerance	Water & soil salinity	Average root zone salinity
Sensitive crops	Very low	<0.95
Moderately sensitive crops	Low	0.95-1.9
Moderately tolerant crops	Medium	1.9-4.5
Tolerant crops	High	4.5-7.7
Very tolerant crops	Very high	7.7-12.2
Very saline	Extreme	>12.2

Soil salinity problems

- Salinity of water and specific ions in water affect plants and soil's permeability.
- Soil salinity may be controlled by leaching.
- Soil compaction & poor drainage worsen soil salinity.

Salt tolerance of plants

- Salt tolerance is highly species dependent.
- Every plant can tolerate certain range of salinity - threshold.
- Salt tolerance of plant is affected by climate and irrigation method.

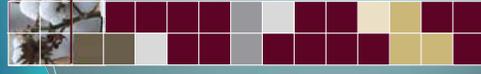
Plant responses to elevated salinity

Herbaceous annuals and perennials

10 Annual species

- *Angelonia angustifolia* 'Lavender Pink'
- *Angelonia angustifolia* 'Purple'
- *Angelonia angustifolia* 'White'
- *Capsicum annuum* 'Black Pearl'
- *Capsicum annuum* 'Calico'
- *Capsicum annuum* 'Purple Flash'
- *Catharanthus roseus* 'Titan'
- *Helenium amarum* 'Dakota Gold'
- *Helichrysum petiolarum* 'Silver Mist'
- *Plumbago auriculata* 'Escapade Blue'

Materials and Methods



- 5 levels of salinity: 0.8 (Tap water), 2.8, 4.0, 5.0, or 7.4 dS/m.
- Saline solutions were prepared in 100 L tank by adding NaCl, MgSO₄, CaCl₂ to tap water at 85:8:5 (by weight).
- Plants were irrigated as needed.



Angelonia 'Purple'

Salinity (EC) – dS/m

0.8 2.8 4.0 5.1 7.4

Photos were taken after 2.5 months



EC 0.8

'Purple'

EC 7.4

Angelonia 'White'

0.8 2.8 4.0 5.1 7.4

'Lavender Pink'

0.8 2.8 4.0 5.1 7.4

'Lavender Pink'

EC 0.8 EC 7.4

Orn. Pepper 'Black Pearl'

0.8 2.8 4.0 5.1 7.4

'Black Pearl'

EC 0.8 EC 7.4

Orn. pepper 'Calico'

0.8 2.8 4.0 5.1 7.4

'Calico'

EC 0.8 EC 7.4

Orn. pepper 'Purple Flash'

0.8 2.8 4.0 5.1 7.4

'Purple Flash'

EC 0.8 EC 5.0

Helenium 'Dakota Gold'



Licorice plant 'Silver Mist'



Vinca 'Titan'



Plumbago 'Escapade Blue'



Control



EC 7.0



Salts exuded from leaves, mostly from back of the leaf.

Summary (for the 10 annuals)

- Salinity tolerance varied with species.
- The threshold was 3.5 dS/m for angelonia and 'Calico'; 3.5 – 5.0 dS/m for Licorice plant, helenium, and plumbago.
- 'Black Pearl' and vinca tended to have greater growth reduction.

Cultivars

NuMex Twilight	NuMex Centennial
NuMex Christmas	NuMex April Fool's Day
NuMex Cinco de Mayo	NuMex Valentine
NuMex Easter	NuMex Halloween
NuMex St. Patrick's Day	NuMex Memorial Day
NuMex Thanksgiving	

Salt tolerance of 11 cultivars of ornamental peppers

Halloween



Day 0

Easter



Day 0

Salinity Treatments

- Three treatments: 1.3 (control, nutrient solution), saline solutions at EC 4.1 and 8.1 dS/m.
- Saline solutions were prepared in 100 L tank by adding NaCl, and CaCl₂ salts to nutrient solution at 2:1 molar ratio.

Materials & Methods

- Seeds were sown on June 2 and germinated seedlings were transplanted to 6-in pots filled with sunshine mix # 4.
- Treatments were initiated on July 15.

Memorial Day



EC 8 EC 4 EC 1.3

Christmas



EC 8 EC 4 EC 1.3

Valentines



EC 8 EC 4 EC 1.3

St. Patrick



EC 8 EC 4 EC 1.3

Halloween



EC 8 EC 4 EC 1.3

Easter



EC 8 EC 4 EC 1.3

Centennial



EC 8 EC 4 EC 1.3

April Fool's



EC 8 EC 4 EC 1.3

Twilight



EC 8 EC 4 EC 1.3

Thanksgiving



Cinco de Mayo



EC 8 EC 4 EC 1.3

Visual Scores

Based on foliar damage:

- 0 – dead
- 1 – >75%
- 2 – 50% -75%
- 3 – 15% - 50%
- 4 – <15%
- 5 – Excellent

Cultivar Visual Score (EC 8.1)

Memorial	2.45
Christmas	4.69
Valentines	4.83
St. Patrick	4.87
Halloween	4.88
Easter	4.91
Centennial	4.98
April Fools	4.99

Shoot DW reduction (%) EC 8 vs. EC 1.3

Twilight , 37	Centennial, 51
Christmas, 53	April Fool's, 37
Cinco de Mayo, 32	Valentine, 34
Easter, 46	Halloween, 35
St. Patrick, 48	Memorial Day, 74
Thanksgiving, 15	

Growth Index reduction (%) EC 8 vs. EC 1.3

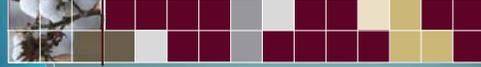
Twilight , 34	Centennial, 28
Christmas, 23	April Fool's, 14
Cinco de Mayo, 14	Valentine, 21
Easter, 30	Halloween, 19
St. Patrick, 23	Memorial Day, 37
Thanksgiving, 33	

Summary

- All cultivars were moderately tolerant to saline water irrigation except for 'NuMex Memorial Day'.
- All cultivars except 'NuMex Memorial Day' can be planted in landscapes where low quality water may be used for irrigation.

Salinity Treatments

- 1.4, 2.8, 4.2, 6.0, and 8.0 dS/m.
- Saline solutions were prepared in 100 L tank by adding NaCl, MgSO₄, CaCl₂ salts to nutrient solution at 85:8:5 (by wt).



Response of *Zinnia marylandica* and *Z. maritima* Cultivars to Salinity

Cultivars

- Z. marylandica* 'Coral Rose'
- Z. marylandica* 'Fire'
- Z. marylandica* 'Rose Starlight'
- Z. marylandica* 'Scarlet'
- Z. marylandica* 'White'
- Z. marylandica* 'Yellow'
- Z. maritima* 'Solcito'



Stunt Growth

As salinity increased



Zinnia marylandica 'Fire' – 2 weeks after Treatments at EC 1.5 to 8.2 dS/m

Foliar damage/mortality

As salinity increased



Zinnia marylandica 'Fire' – 25 days after Treatments at EC 1.5 to 8.2 dS/m

Petunia

Baby Duck Yellow , 42 d, Apr 28, Control



Baby Duck Yellow , 42 d, Apr 28, EC 8



Mirage Rose, 42 d, Apr 28, Control



Mirage Rose, 42 d, Apr 28, EC 8



Spreading, 42 d, Apr 28, control



Spreading, 42 d, Apr 28, EC 8



Woody Shrubs and Trees

Green Ash
(*Fraxinus pennsylvanica*)



One month after

0.8

2.0

4.0 dS/m

3 months after

0.8

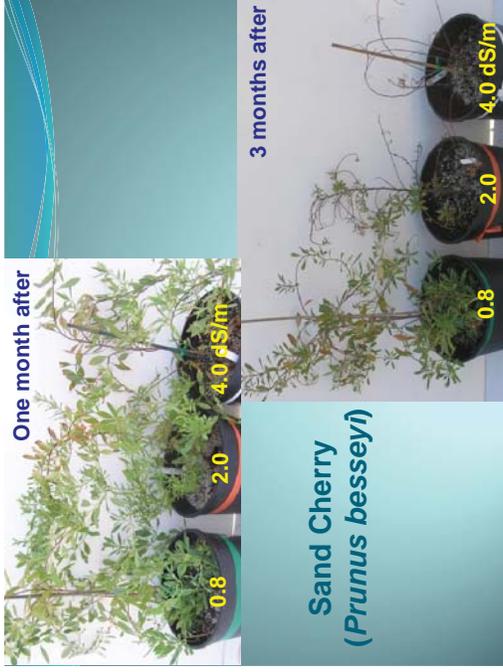
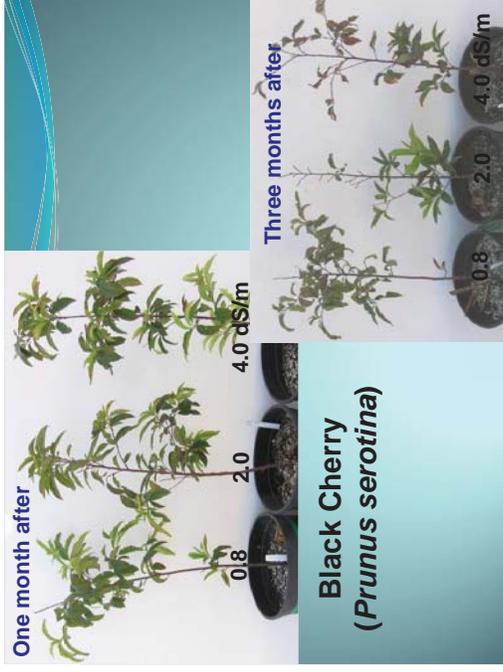
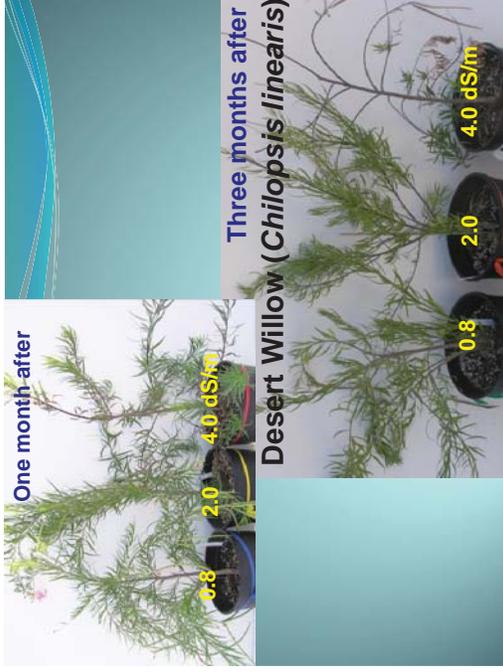
2.0

4.0 dS/m

0.8

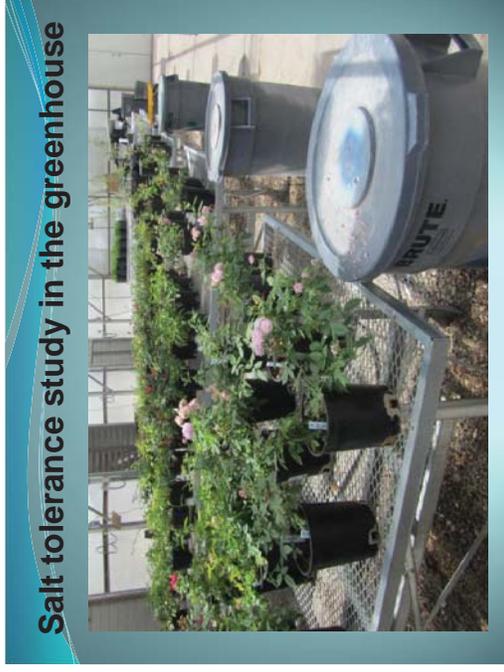
2.0

4.0 dS/m



Assessment of salt tolerance

- Salt tolerance of a plant is defined as the ability to withstand the effects of high salinity without significant adverse effects (reduced growth, yield, foliar injury, etc.).
- Salt tolerance can be assessed quickly based on visual quality and growth.
- To understand the salt tolerance mechanism, quantify physiological responses.



Field salinity study



- Greenhouse studies provide the relative salt tolerance among species.
- The absolute salinity threshold needs to be confirmed outdoor.
- Extrapolate results from greenhouse to field.

General responses of plants to salinity

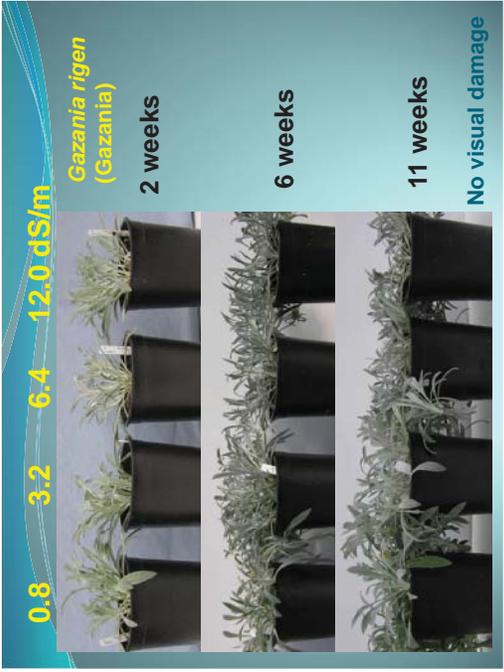
Salt tolerance of herbaceous annuals and perennials



Salinity Treatments

- 0.8 dS/m (tap water, 550 ppm TDS)
- 3.2 dS/m (2000 ppm)
- 6.4 dS/m (4000 ppm)
- 12 dS/m (8000 ppm)

Saline solution: NaCl, MgSO₄, CaCl₂ (87:8:5, weight ratio) to simulate the composition of EPWU's reclaimed water



Other salt tolerance studies



Petunia 'Spreading', 42 d



Control



EC 8.0

Gazania rigen 'Pink Shade' subirrigated for 33 days



Control



EC 8.0

Tagetes erecta 'Gold' Subirrigated for 39 days



Control



EC 2.8

Salt tolerance of 10 herbaceous perennials & groundcovers (outdoor)

Species

- *Achillea millefolium* (Yarrow)
- *Gaillardia aristata* (Firewheel)
- *Glandularia canadensis* (Homestead verbena)
- *Glandularia x hybrida* (Garden verbena)
- *Lantana montevidensis* (Purple lantana)
- *Lantana x hybrida* 'New Gold' (lantana)
- *Lonicera japonica* (Honeysuckle)
- *Rosmarinus officinalis* (Rosemary)
- *Rudbeckia hirta* (Black-eyed Susan)
- *Verbena macdougallii* (Spike verbena)

No visual injury

Rosemary



Honeysuckle



Lantana 'New Gold'



Yarrow



Rudbeckia hirta (Blackeyed Susan)

Control



3.2 dS/m



5.4 dS/m

1 month later



3 month later



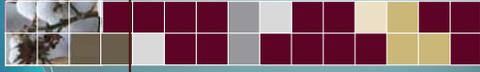
Salt tolerance of garden roses

Garden roses



Salt tolerance of rose rootstocks

- Four rose rootstocks
- 'Dr. Huey' (*Rosa x hybrida*)
- R. x fortuniana*
- R. multiflora*
- R. odorata*



Salinity Treatment

	EC (ds/m)	Cl ⁻ or SO ₄ ²⁻
Control	1.6	
Moderate - Cl	3.9	Cl - dominated
Moderate -SO ₄	3.9	SO ₄ -dominated
High - Cl	8.2	Cl - dominated
High -SO ₄	7.9	SO ₄ - dominated

'Dr. Huey'

3.9 dS/m

8.0 dS/m



Control M-CI M-SO4 H-CI M-SO4

R. odorata

3.9 dS/m

8.0 dS/m



Control M-CI M-SO4 H-CI M-SO4

R. fortuniana

3.9 dS/m

8.0 dS/m



Control M-CI M-SO4 H-CI M-SO4

R. multiflora

3.9 dS/m

8.0 dS/m



Control M-CI M-SO4 H-CI M-SO4

Summary

- Cl-dominated salinity had greater growth reduction in all rootstocks.
- Four rose rootstocks had different ion uptake.
- Rosa fortuniana* was least tolerant to salinity dominated by Cl, although it was most tolerant when SO₄ was dominant salt.

Salt tolerance of self-rooted rose cultivars

Self-rooted cultivars

Expt. 1

Belinda's Dream
 Carefree Beauty
 Caldwell Pink
 Folksinger
 Quietness
 Winter Sunset

Expt. 2

Bayse's Blueberry
 Iceberg
 Little Buckaroo
 The Fairy
 Marie Pavie
 Rise-N-Shine
 Sea Foam



7 wks - control



Folksinger



Quietness

7 wks after treatment at EC 6.4 dS/m



Folksinger



Quietness

7 wks - control



Belinda's Dream



Caldwell Pink

7 wks after treatment at EC 6.4 dS/m



Belinda's Dream



Caldwell Pink



Carefree Beauty

Winter Sunset

7 wks - control

7 wks after treatment at EC 6.4 dS/m



Carefree Beauty



Winter Sunset



Bayse's Blueberry

Control

EC 6

Photos – Expt. 2
 at the end of the experiment

Iceberg

Control



EC 6



The fairy

Control



EC 6



Little Buckaroo

control



Little Buckaroo

EC 6



Marie Pavie

Control



EC 6



Rise-N-Shine

Control



EC 6



Sea Foam

Control



EC 6



Summary – Expt. 1

- Belinda's Dream and Caldwell Pink were relatively tolerant, while Carefree Beauty and Winter Sunset were sensitive.



Summary – Expt. 2

- Plants in Expt. 2 had relatively no or minor foliar salt damage, evidenced by low uptake of Na and Cl.
- Iceberg, Marie Pavie and The Fairy had greater DW reduction at EC 6.
- Little Buckaroo did not have foliar damage.



Is drought tolerant plants tolerate salt stress?

- We have not seen any “correlation” between drought and salt tolerance.
- Both drought and salt tolerance are highly species dependent.
- Initial responses are similar – stunt growth, low transpiration rate, etc.

Herbaceous plants tolerate both drought and salt stresses

- Ornamental peppers (a number of cultivars).
- Lantana, honeysuckle, rosemary
- Blanket flower, yarrow
- Angelonia, helenium, blue plumbago

Herbaceous plants tolerate drought but **NOT** to salt

- *Zinnia Marylandica*, *Z. maritima* ‘Solcito’



Drought tolerant but only moderately tolerant to salt



Concluding Remarks

- Large variations in salt tolerance exist among tested species.
- Salt tolerance depends on species, environmental conditions, and irrigation management.
- Mechanisms – ion uptake restriction, osmotic adjustment

Additional information

- Aggie Horticulture (<http://aggie-horticulture.tamu.edu/>)
- Lady Bird Johnson Wildflower Center < www.wildflower.org/ >
- www.salinitymanagement.org maintained by the Southern California Salinity Coalition (SCSC) and National Water Research Institute (NWRI).