

Getting the Most Out of New, Old and Combo PGRS

Roberto G. Lopez
Michigan State University
Department of Horticulture



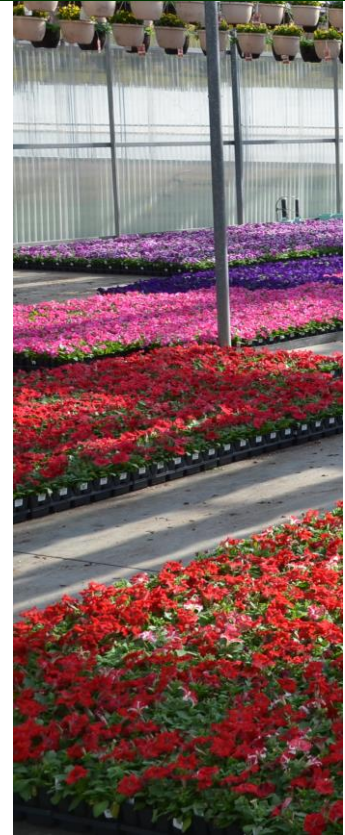
**NORTHEAST
GREENHOUSE
CONFERENCE AND EXPO** 2023

Determining Rates and Volumes for Foliar Rooting Hormones



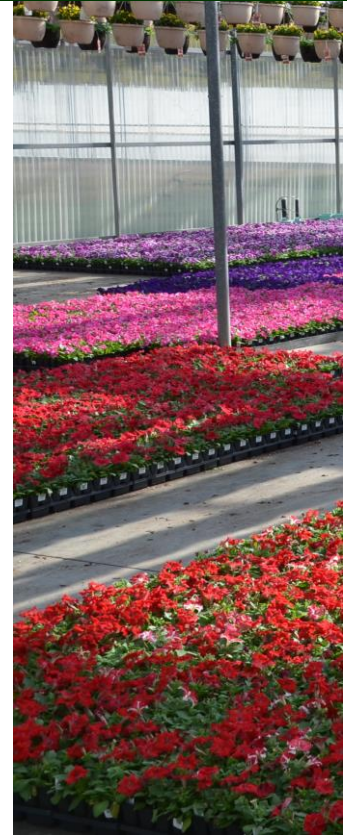
Rooting Hormones

- Rooting hormones contain auxin (IAA, IBA, KIBA, or NAA) that are involved in cell elongation and adventitious root formation.
- Are not required for the majority of species to achieve nearly 100% rooting success.
- Difficult- or slow-to-root species and cultivars are often treated to increase:
 - Uniformity of rooting
 - Speed of rooting
 - Root mass



Rooting Hormones

- Liquid or powder rooting hormones can be applied to the basal end of cuttings
 - generally range between 1,000 and 1,500 ppm for annuals
 - generally range between 50 and 300 ppm for perennials
 - Labor intensive
 - Dipping can spread diseases
- Can increase leaf yellowing by increasing the export of sugars from the leaves.



Basal End Applications

- Powdered hormone can be applied to basal end of the cutting.
- Use a duster to apply to the stem only.
- Avoid getting powdered hormone on the leaves.
- Do not dip the stem into a container of hormone....this is a sanitation risk.
- Do not coat the stem with a solid layer of powder.

Powder Applications



Basal End Applications

- IBA can be applied as a liquid basal application with typical rates of 1,000 to 1,500 ppm.
- Apply to the basal end with a hand-held spray bottle.
- Do not allow solution to get on the stems or leaves of the cutting.
- Do not dip stems directly into the solution.....this is a sanitation risk.



Liquid Applications

Rooting Hormones

- Liquid or powder rooting hormones can be applied to the basal end of cuttings
 - Labor intensive
 - Dipping can spread diseases
- Overhead rooting hormone application after cuttings have been stuck.
- Can increase leaf yellowing by increasing the export of sugars from the leaves.



Rooting Hormones Beneficial

Annuals in this category will root without using rooting hormones, but will generally root faster or more uniformly with their use.

Rooting Hormone Beneficial		
Alternanthera	Diascia	Santolina
Angelonia	Fuchsia	Torenia
Argyranthemum	Gazania	Viola
Bacopa	Geranium zonal	Vinca
Begonia hiemalis, reinger, rex	Helichrysum	
Bougainvillea	Lobelia	
Bidens	Lobularia	
Calocephalus	Oternaria	
Cuphea	Poinsettia	

Rooting Hormones Beneficial

Perennials in this category will root without using rooting hormones, but will generally root faster or more uniformly with their use.

Rooting Hormone Beneficial		
Artemesia	Heliopsis	Veronica
Buddleia	Hypericum	Vinca minor
Campanula	Lavender	
Coreopsis	Leucanthemum	
Delosperma	Malva	
Erysimum	Penstemon	
Euonymus	Phlox <i>paniculata</i> and <i>subulata</i>	
Eupatorium	Rosemary	
Geranium	Salvia	
Hedera	Scabiosa	

Rooting Hormones Essential

Annuals in this category are more difficult to root and there is a higher value of using rooting hormones

Rooting Hormone Essential	
Bracteantha	Mandevilla/ Dipladenia
Calibrachoa on certain cultivars	Nemesia
Crossandra	Osteospermum
Dahlia	Perricalis
Gazania	Salvia
Heliotrope	Regal geranium
Hibiscus	Scaevola
Lantana	Thunbergia
Lobelia	



Rooting Hormones Essential

Perennials in this category are more difficult to root and there is a higher value of using rooting hormones

Rooting Hormone Essential

Baptisia

Dianthus

Dracaena

Euphorbia

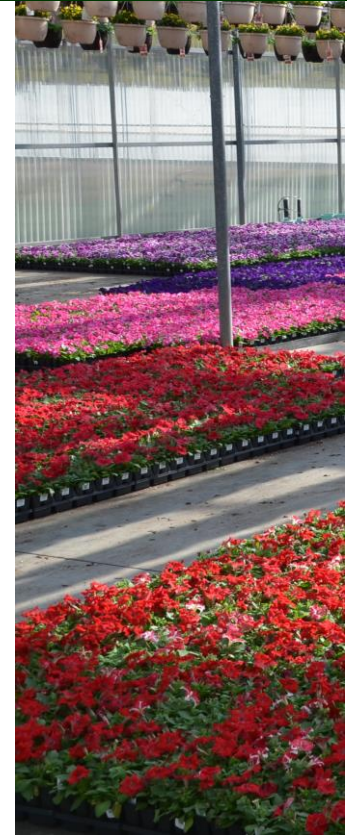
Gypsophila

Heuchera

Hydrangea

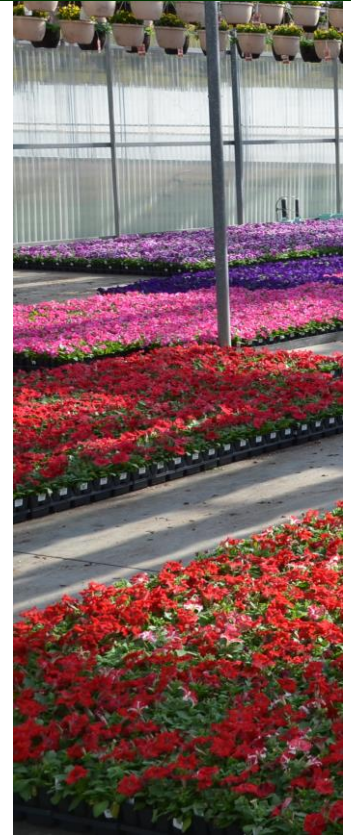
Iberis

Lithodora



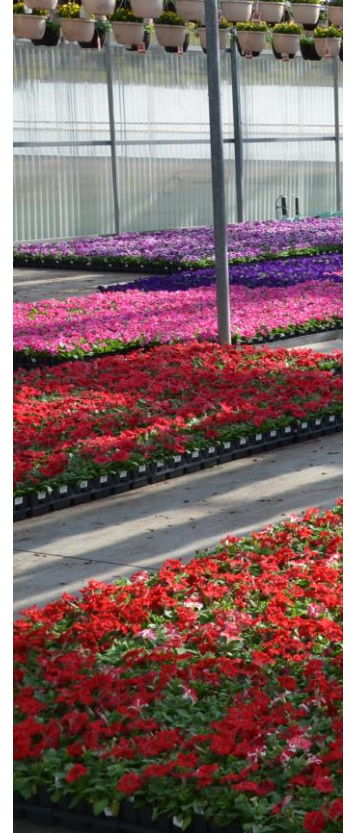
Spray Application after Sticking

- Coarse spray over the crop so that some of the solution runs down the stem toward the base of the cutting.
- The potassium-salt formulation of IBA is often used as it is water soluble (KIBA), and therefore causes less foliar damage compared to alcohol-soluble formulations
 - 50 to 500 ppm KIBA (@ day 1 or 2 after stick)

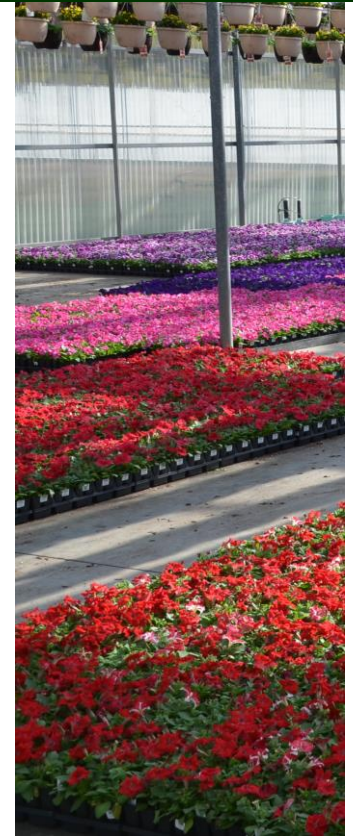


Rooting Hormones

Scaevola received a 200 ppm IBA overhead rooting hormone application

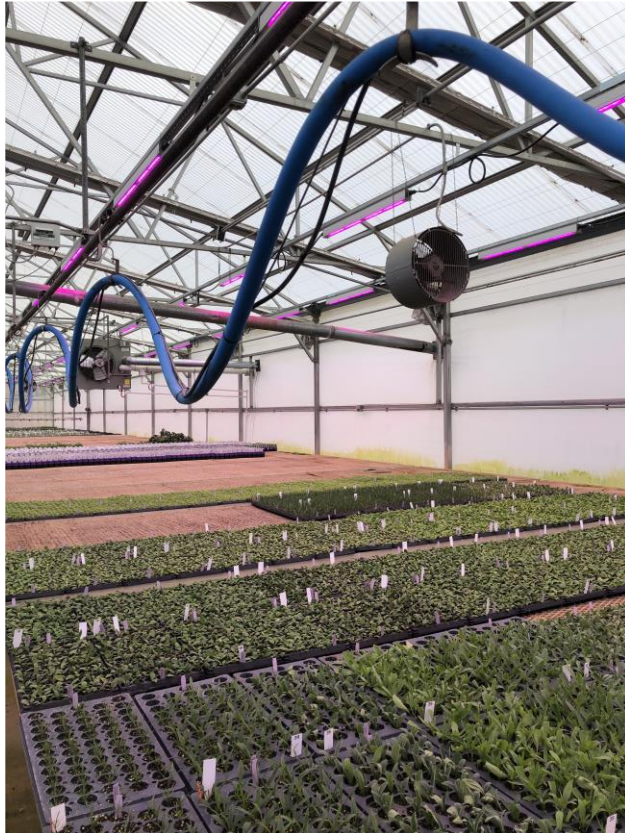


Argyranthemum showing leaf curl (epinasty) after overhead IBA+NAA spray



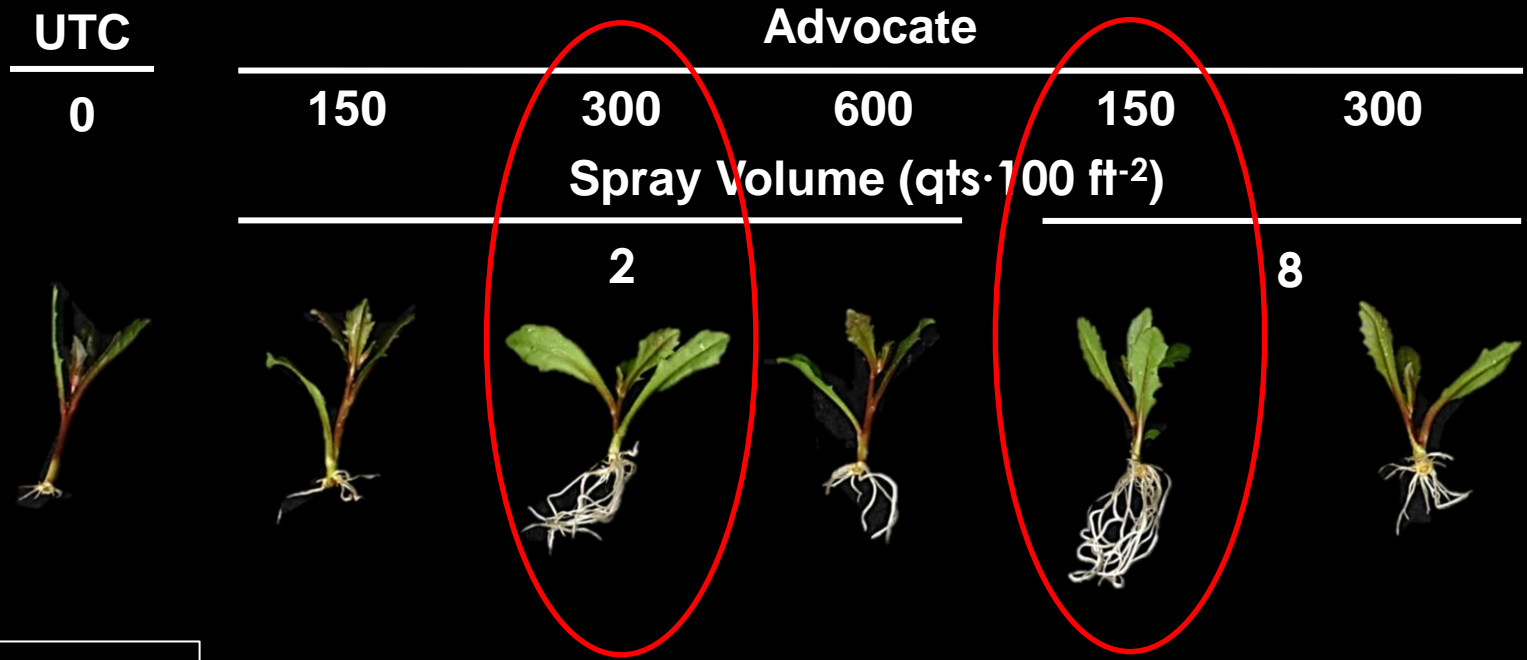
Jason Twaddell, Ball FloraPlant

Spray Application after Sticking



Scaevola 'Brilliant'

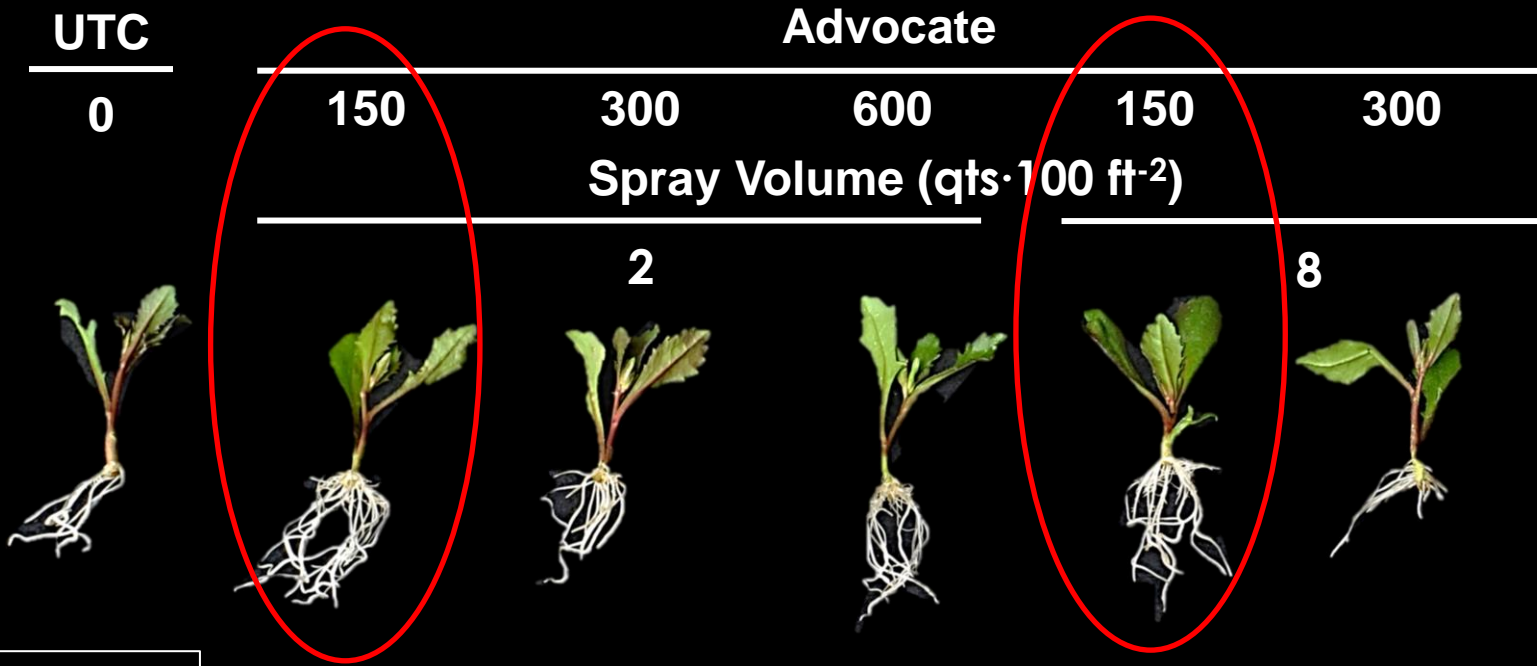
Foliar spray applications (ppm)



High DLI
11.9 ± 1.5 mol·m⁻²·d⁻¹

Scaevola 'Brilliant'

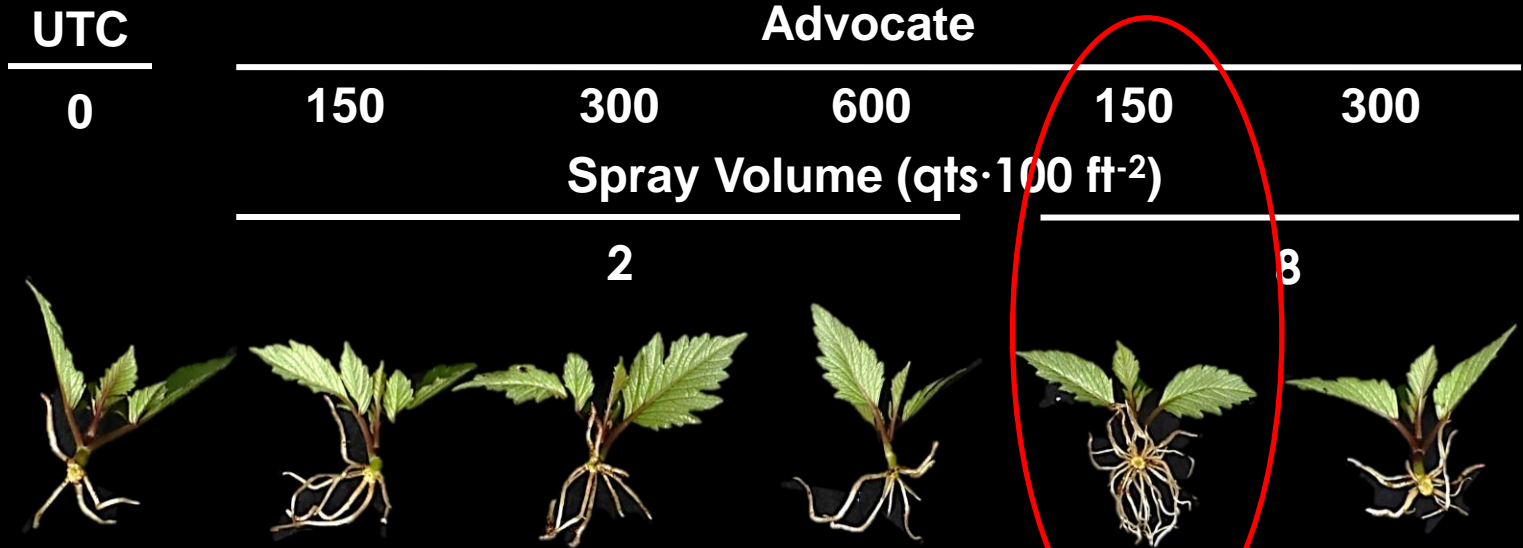
Foliar spray applications (ppm)



Very High DLI
15.7 ± 3.4 mol·m⁻²·d⁻¹

Dahlia 'Passion Fruit'

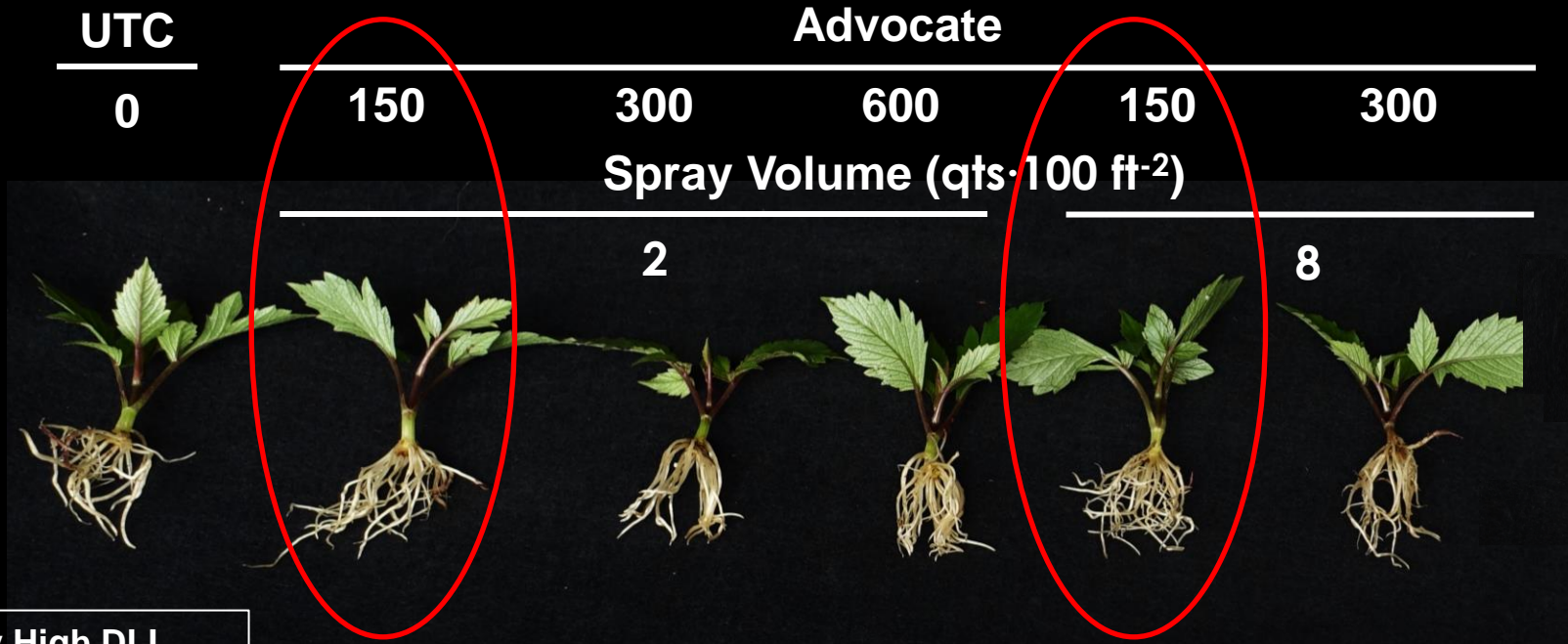
Foliar spray applications (ppm)



High DLI
 $11.9 \pm 1.5 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$

Dahlia 'Passion Fruit'

Foliar spray applications (ppm)



Very High DLI
 $15.7 \pm 3.4 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$

Osteospermum 'Lavender Frost'

Foliar spray applications (ppm)

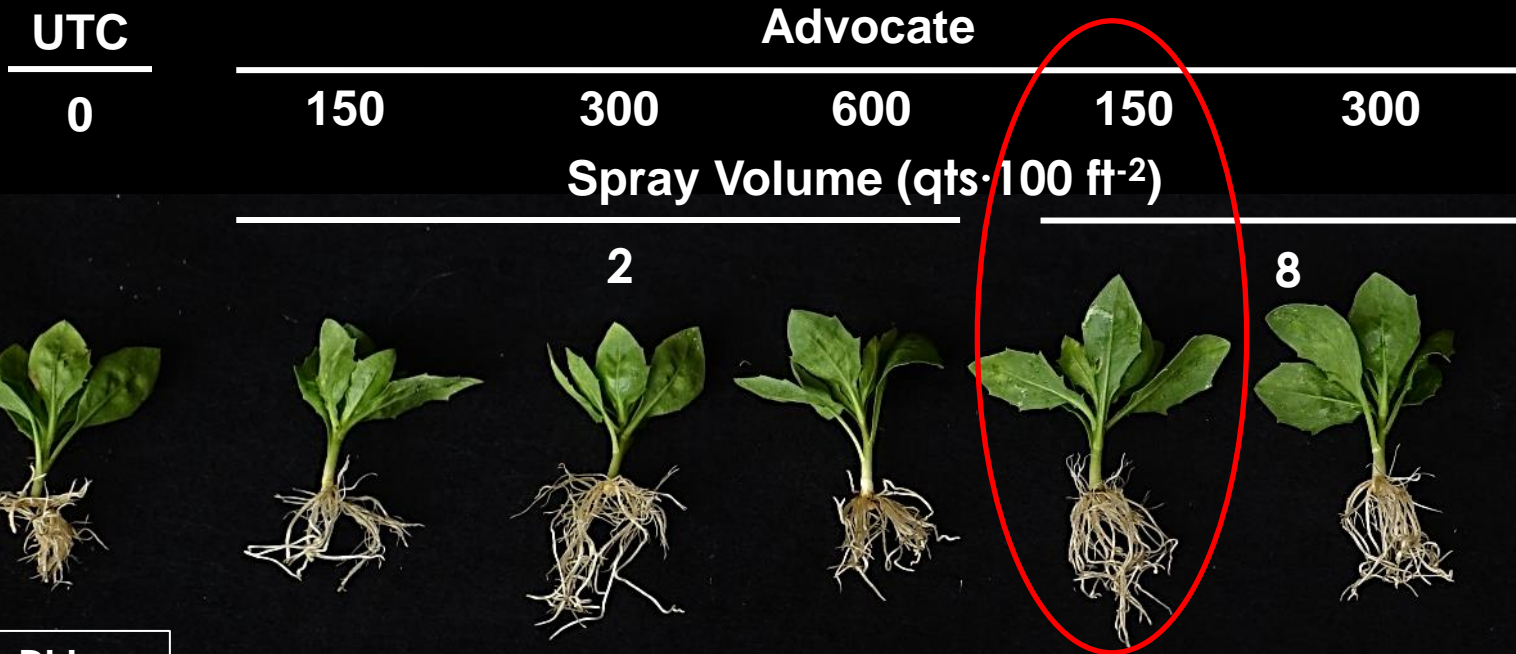
UTC	Advocate				
0	150	300	600	150	300
	Spray Volume (qts·100 ft ⁻²)				
		2		8	



High DLI
11.9 ± 1.5 mol·m⁻²·d⁻¹

Osteospermum 'Lavender Frost'

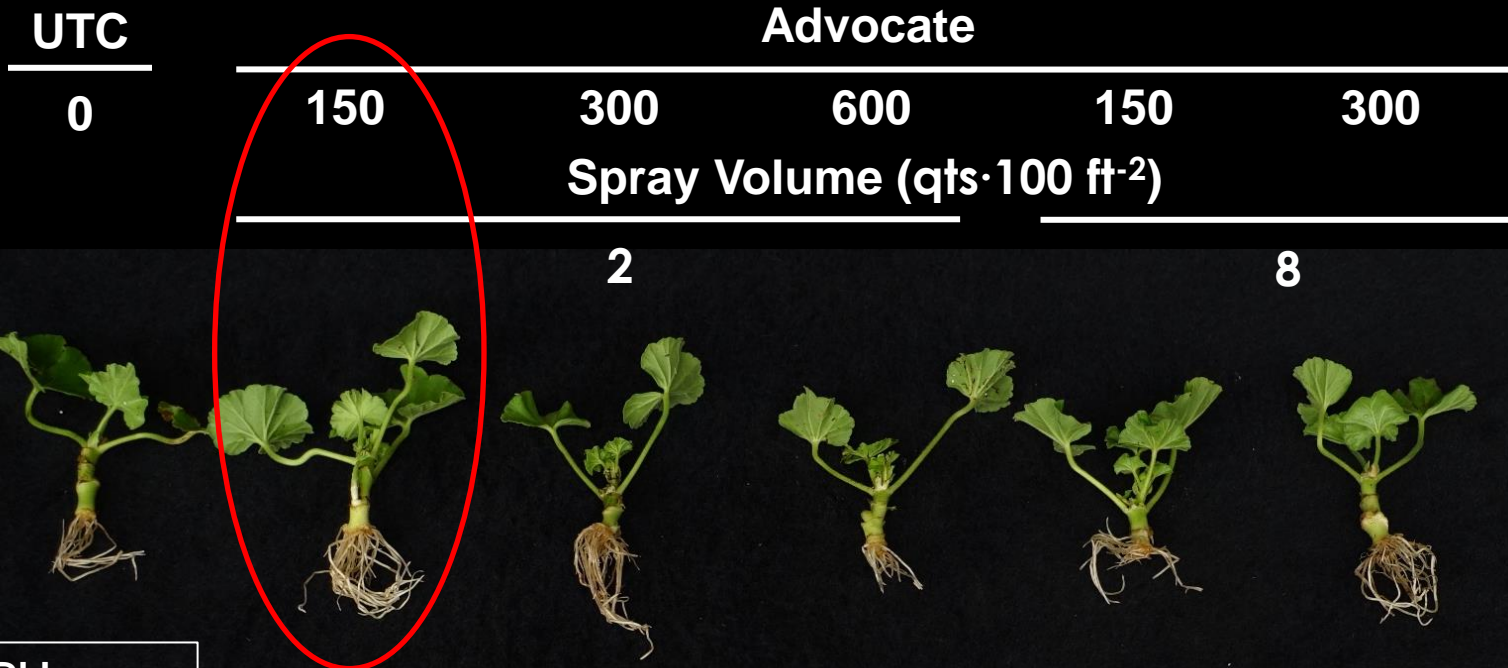
Foliar spray applications (ppm)



Very High DLI
 $15.7 \pm 3.4 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$

Geranium 'Lavender + Red Eye'

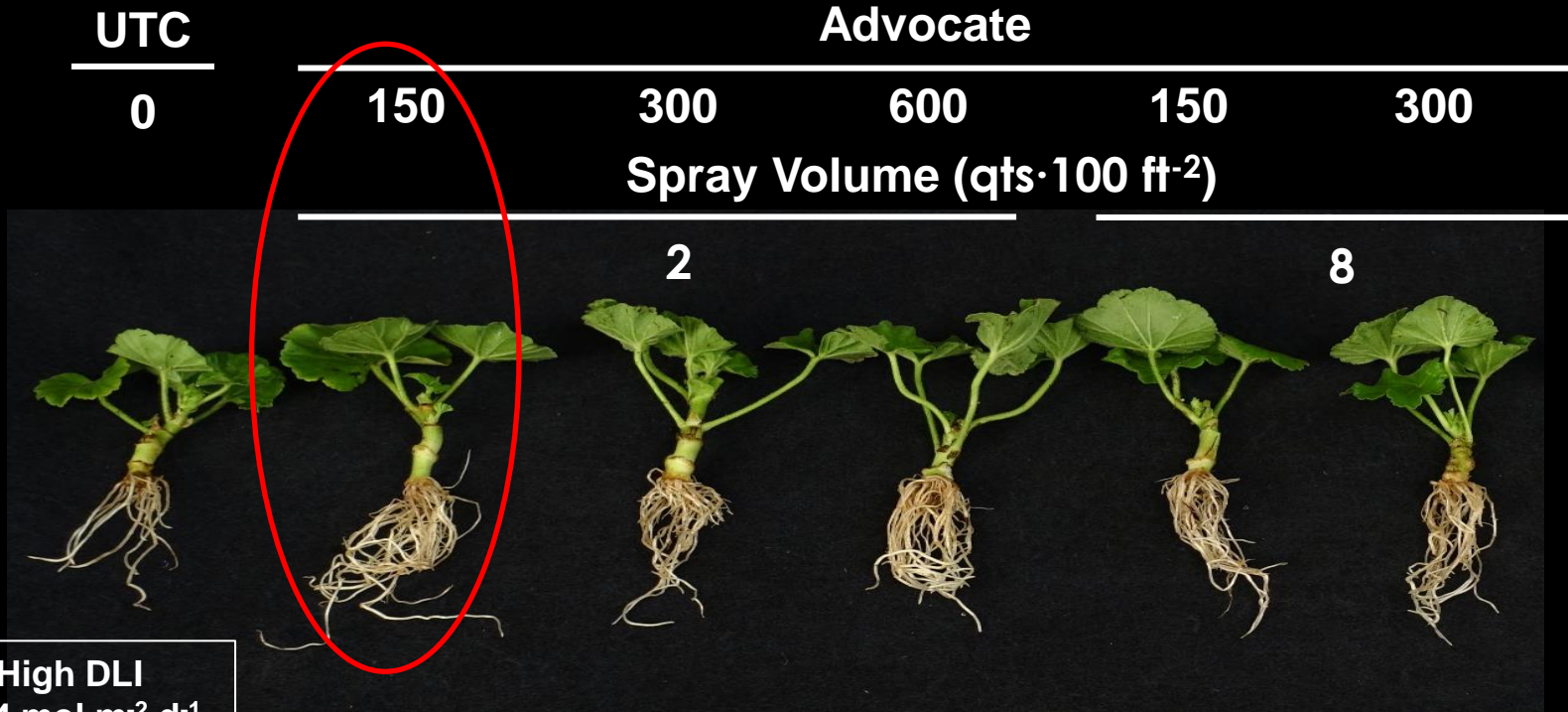
Foliar spray applications (ppm)



High DLI
 $11.9 \pm 1.5 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$

Geranium 'Lavender + Red Eye'

Foliar spray applications (ppm)



Mandevilla 'Agate White Vining'

Foliar spray applications (ppm)

UTC

Advocate

0

300

Spray Volume (qts·100 ft⁻²)

2

4

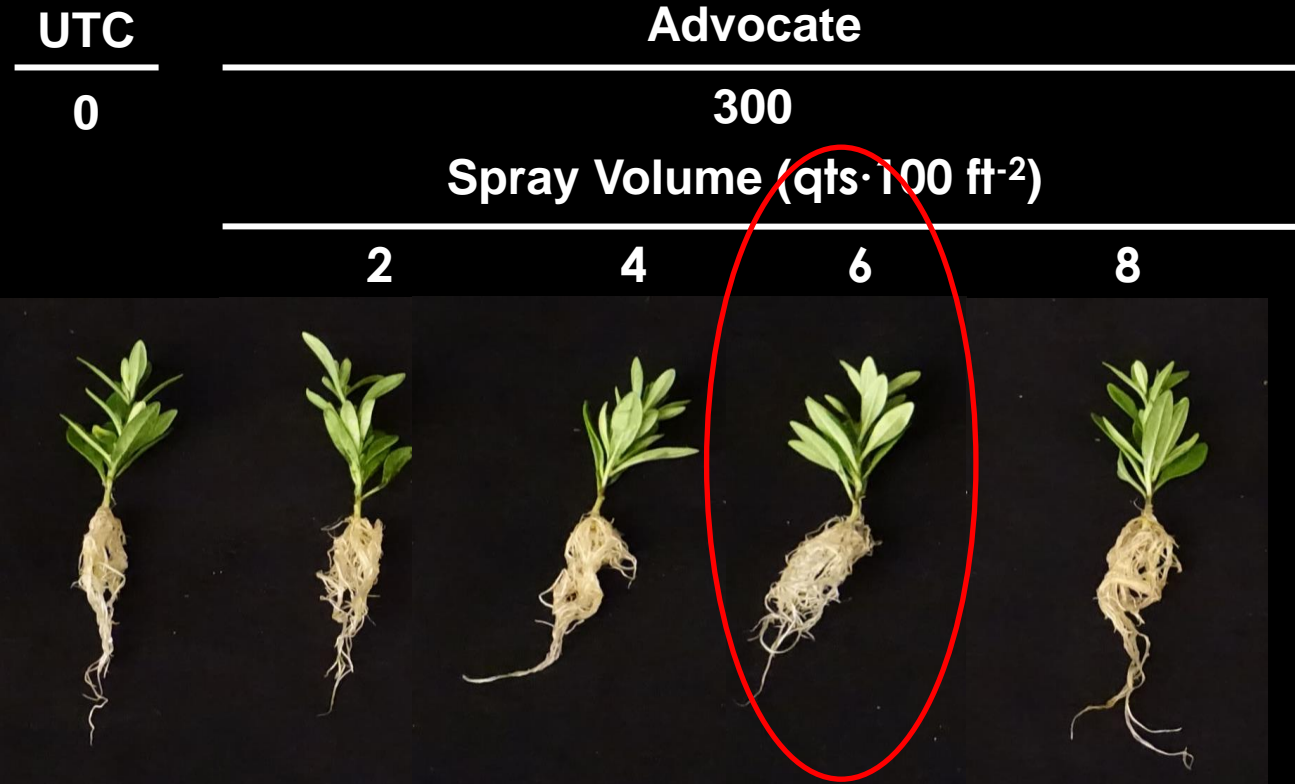
6

8



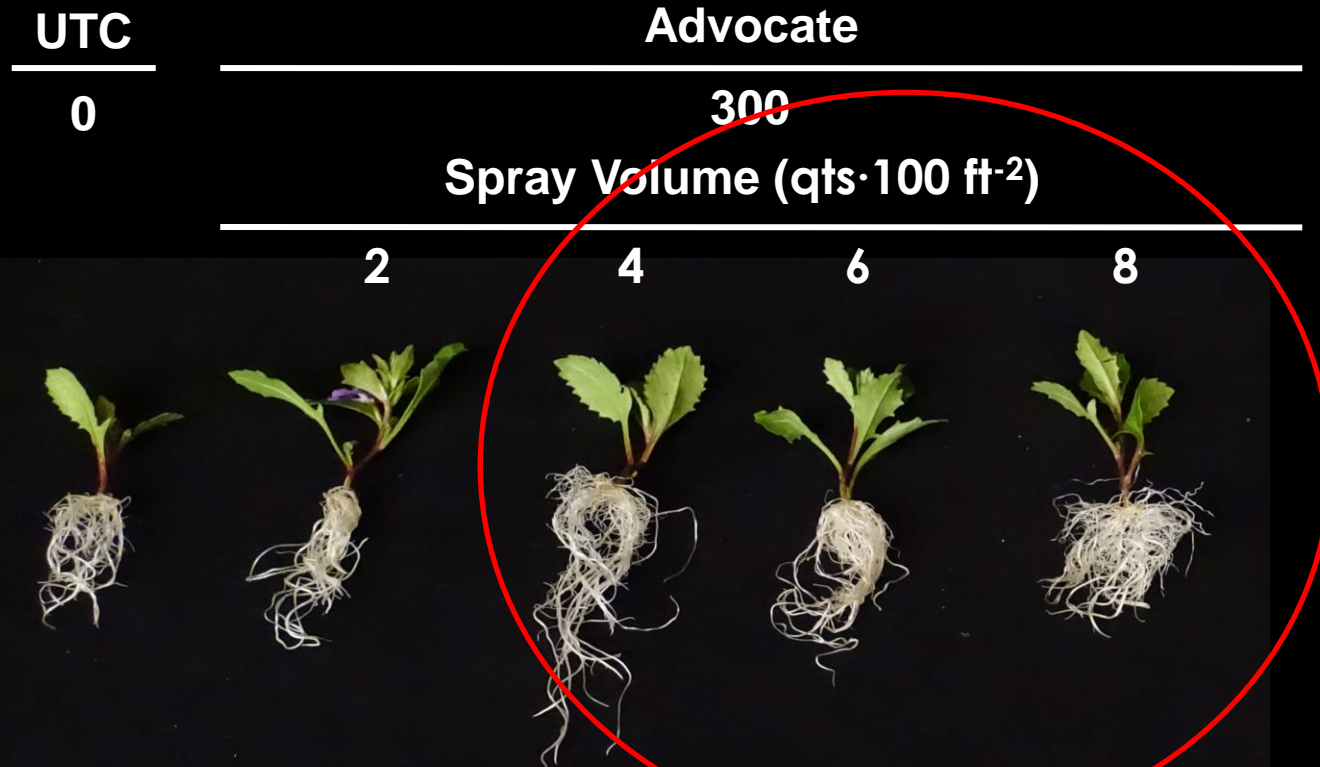
Calibrachoa Cabaret® 'Hot Pink'

Foliar spray applications (ppm)



Scaevola 'Blue Fan'

Foliar spray applications (ppm)



Bidens 'Bidy Boom Red'

Advocate applications (300 ppm)

Control



Foliar
Spray



Basal
Dip



Cutting
Immersion



Begonia elatior 'Rhine Nadine'

Advocate applications (300 ppm)

Control

Foliar
Spray

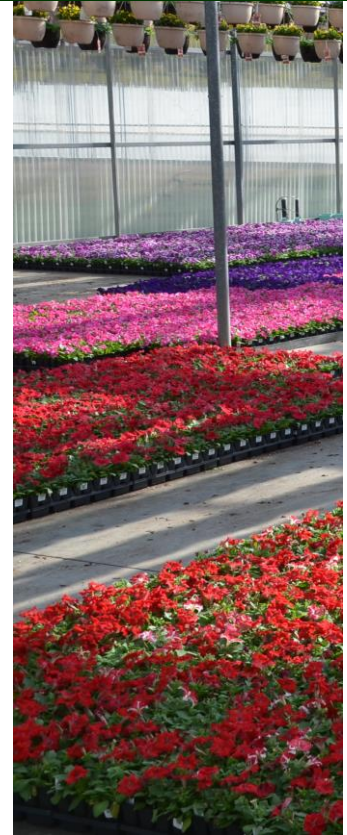
Basal
Dip

Cutting
Immersion



Overhead Rooting Hormone Conclusions

- Under lower light conditions ($\leq 11 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$), difficult to root species such as scaevola may require a higher spray volume application.
- Daily light integral (DLI) and rooting hormone application interact and result in improved rooting for scaevola and geranium.



Overhead Rooting Hormone Conclusions

Products labeled for Sprays:

- Advocate (Fine Americas) is a liquid IBA product labeled for overhead and basal applications.
- Hortus (Hortus USA) is a water-soluble salt product labeled for overhead and basal applications.



Take Home Message

- Foliar prays are as effective or more effective than basal dips at promoting rooting in difficult to root crops.
- While submerging cuttings in a rooting hormone solution is also effective at promoting rooting over the control, cuttings developed water-soaked leaves and there was an increased incidence of botrytis



advocate[®]

Rooting Annual
and Perennial Cuttings
with Advocate

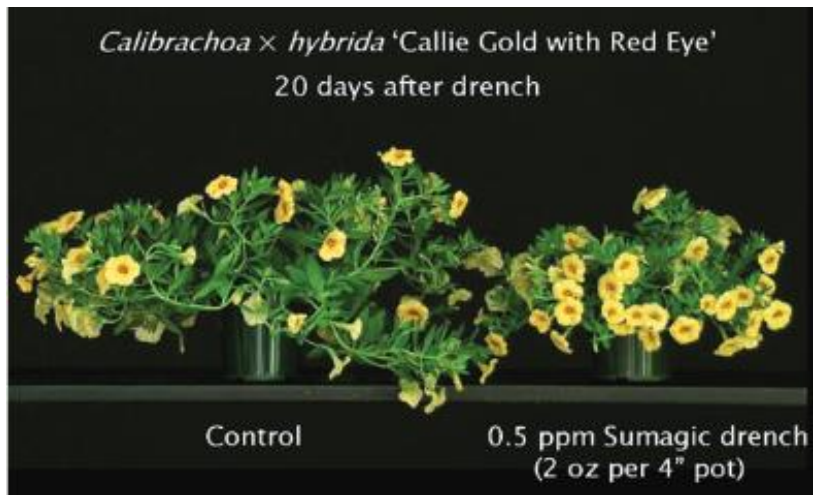


Determining Micro-drenches Rates for Annuals and Perennials



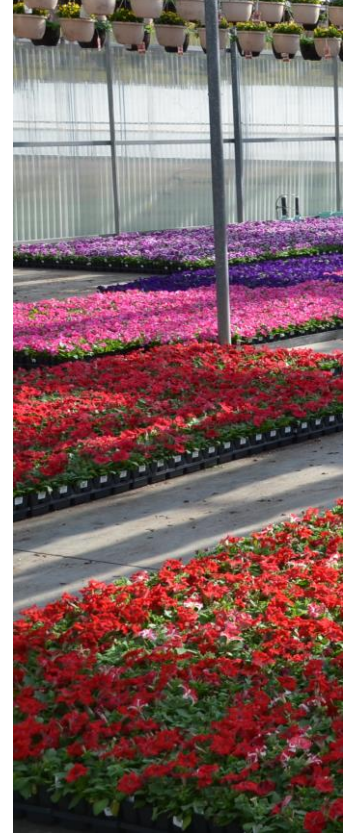
PGR Drenches

- A PGR drench is an application of a relatively large volume of a PGR solution at a low concentration to the growing substrate.



PGR Micro-drenches

- Low dose or micro drenches are much lower (1/10 to 1/8 ppm) than traditional drench rates
 - 3 to 4 applications
 - Less risk of stunting crop and flowering delay
 - Fewer to no residual for consumers



Micro-drench Methods

- **Application Methods:** Substrate micro drench
- **Drench Volume:** sufficient volume insuring treatments are well distributed and retained entirely within the pot (3 fluid ounces per 5" and 4 fluid ounces per 6" pot)
- **Number of Applications:** 1 to 4



Micro-drench Methods

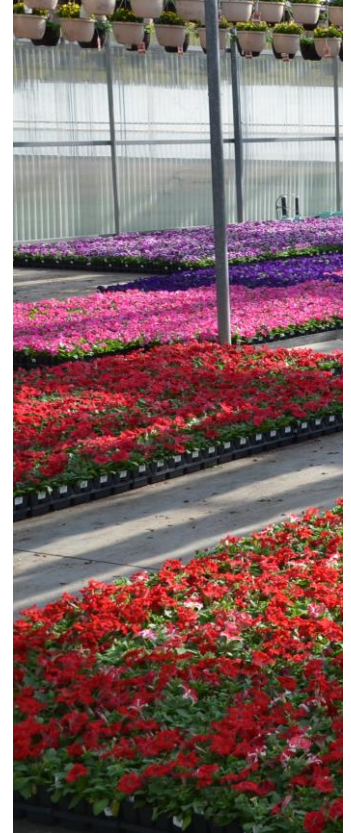
Drench concentrations:

Uniconazole (Concise, Fine Americas)

- Water (control)
- 0.125 ppm
- 0.25 ppm
- 0.05 ppm
- 1.0 ppm

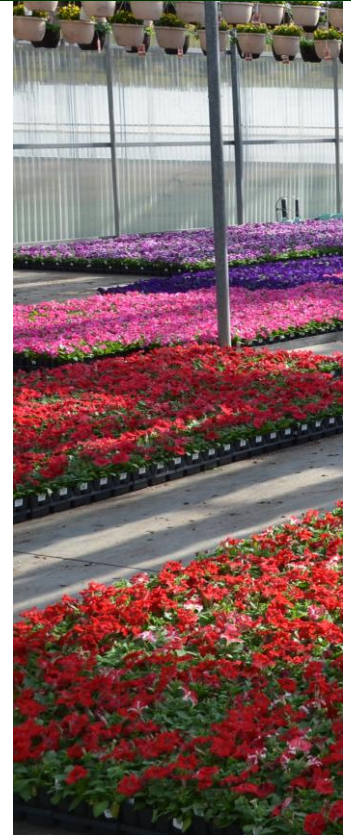
Paclobutrazol (Piccolo, Fine Americas)

- Water (control)
- 0.25 ppm
- 0.50 ppm
- 1.0 ppm
- 2.0 ppm



Micro-drench Methods

- Angelonia 'Big Blue' (5" pot)
- Dianthus 'Rockin Red' (6" pot)
- Hibiscus 'Berry Awesome' (2 gal.)
- Impatiens 'Bounce Cherry' (5" pot)
- Ipomoea 'Sidekick Black' (5" pot)
- Petunia 'Sumo Pink' (5" pot)
- Snapdragon 'Solstice Yellow' (5" pot)
- Verbena 'Endurascape Red' (5" pot)
- Wave Petunia 'Carmine Velour' (6" pot)

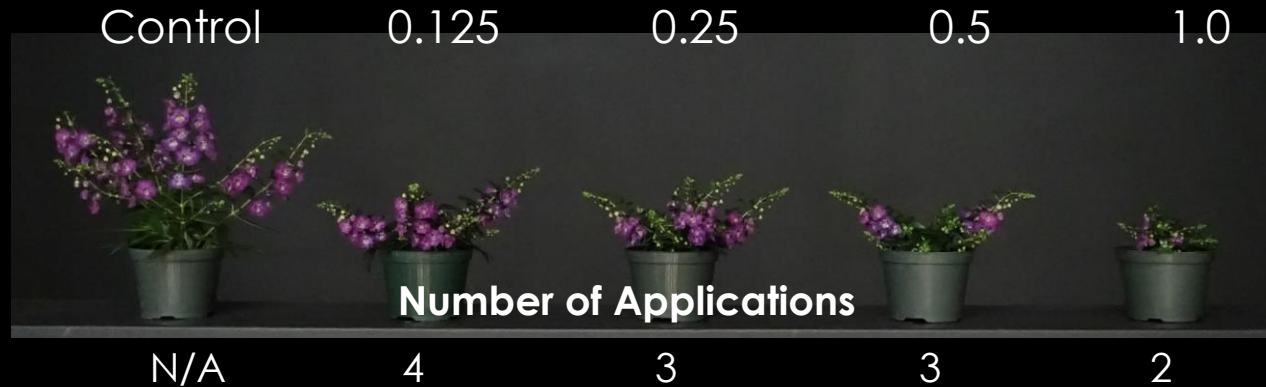


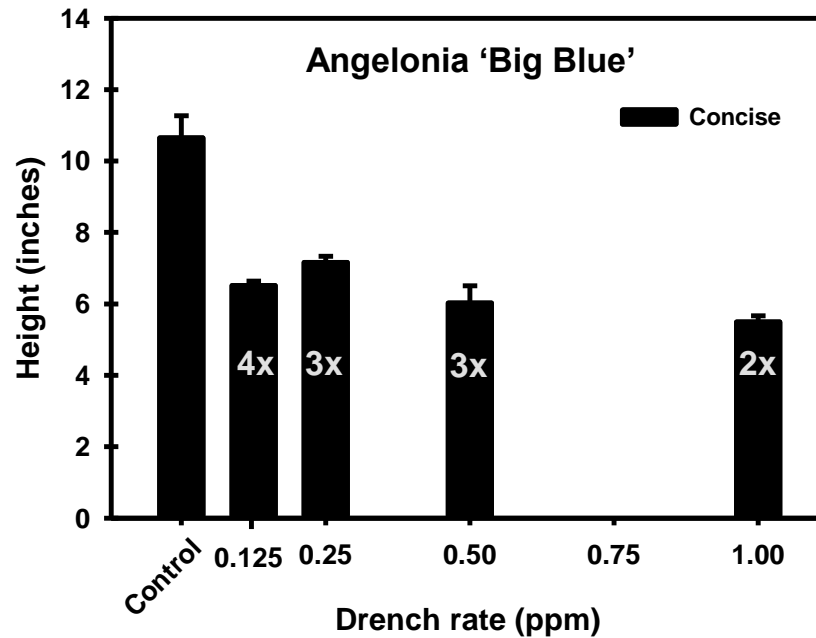
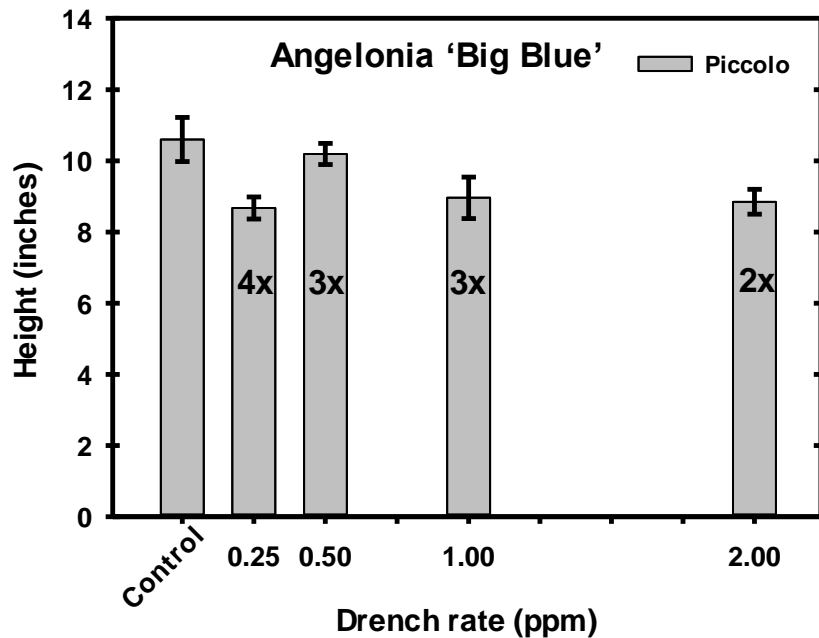
Angelonia 'Big Blue'

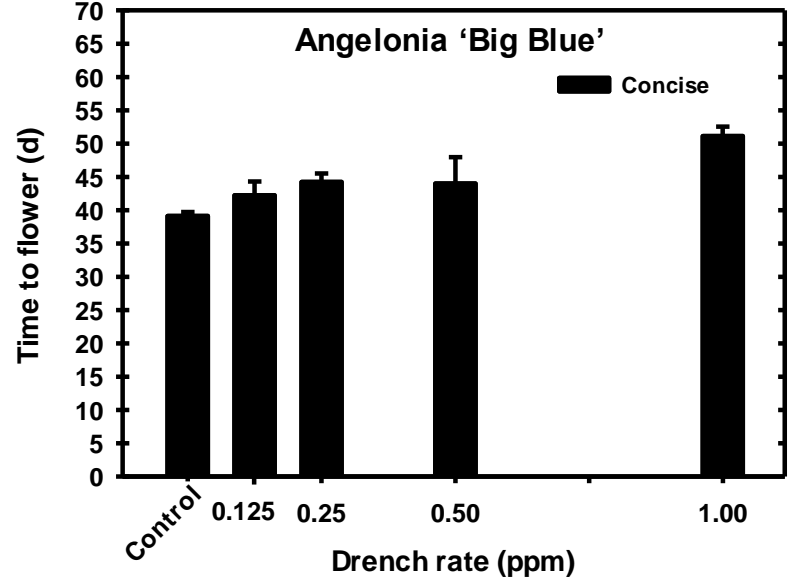
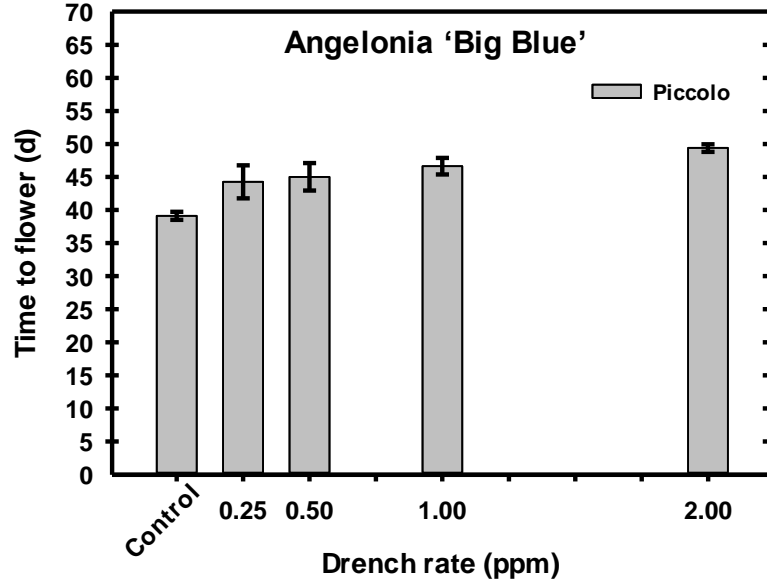
Piccolo Microdrenches (ppm)



Concise Microdrenches (ppm)







Hibiscus 'Berry Awesome'

Piccolo Microdrenches (ppm)

Control

0.25

0.5

1.0

2.0



Number of Applications

N/A

2

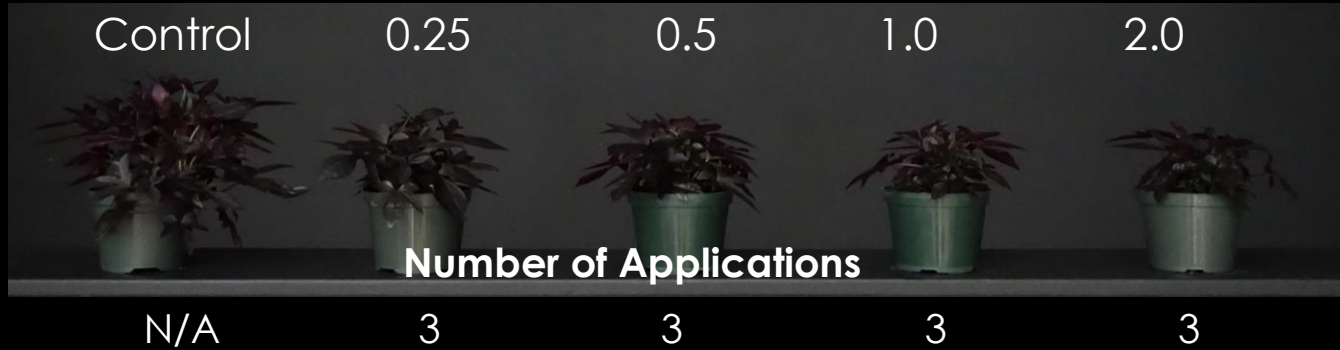
2

1

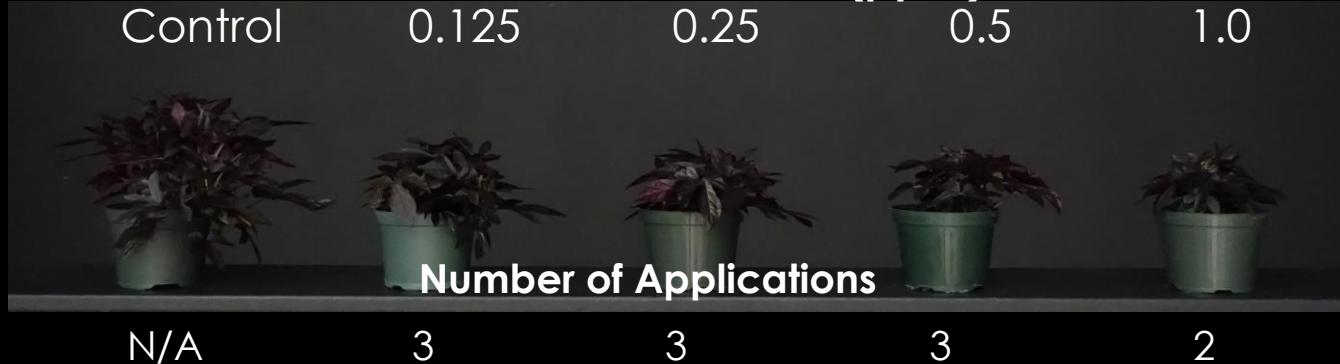
1

Ipomoea 'Sidekick Black'

Piccolo Microdrenches (ppm)



Concise Microdrenches (ppm)



Dianthus 'Rockin Red'

Piccolo Microdrenches (ppm)

Control

0.25

0.5

1.0

2.0



Number of Applications

N/A

3

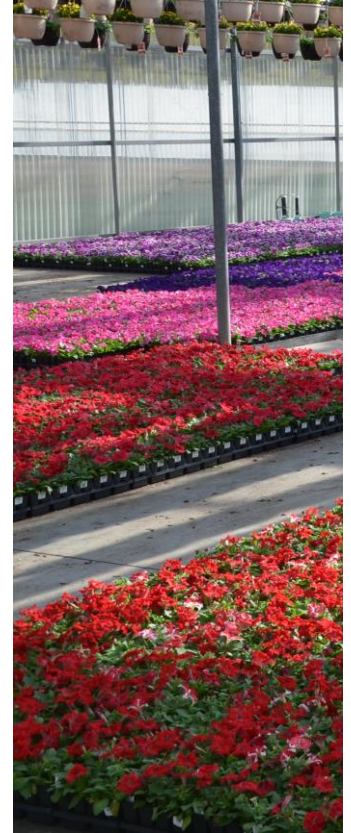
3

3

3

Micro-drench Guidelines

- 7-10 days after transplant is generally the most cost-effective application strategy.
- Delivery by subirrigation generally requires a lower (25-50 percent) rate than those applied to the top of the media.
- Bark can bind to some PGRs and, thus, usually slightly higher rates are required when growing in a media containing bark.
- Conduct your own trials on a small scale to determine appropriate rates for your crops and conditions.



Ethephon Best Management Practices



Why Ethephon?

- Production goals:
 - Compact plants, increased branching, and increased densities
 - Set the flowering clock to zero
- Ethephon (Collate[®] and Florel[®]) is mixed with carrier water to make a spray solution.
- After application, it is converted into the gaseous and active form ethylene.



Why Ethephon?

- Ethylene:
 - suppresses stem elongation
 - increases stem diameter
 - reduces apical dominance causing an increase in branching and lateral growth
 - induces abscission (abortion) of flowers and flower buds



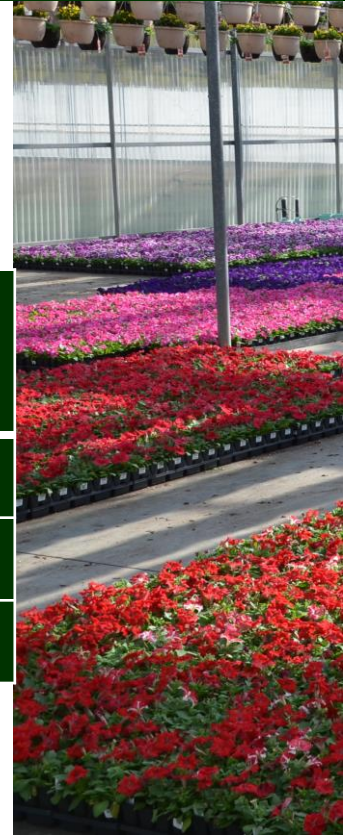
Ethephon (Florel[®] and Collate[®])

- Applications:
 - Sprays: 250 to 500 ppm
- Generally inexpensive
- Achieving consistent results can be trickier than with other PGRs simply because ethylene is a gas.
 - Responses depend on the environment and water quality
 - Can be variable and less predictable

Ethephon (Florel[®] and Collate[®])

- Florel - 3.9 percent active ingredient (U.S.)
- Collate - 21.7 percent active ingredient

Concentration (ppm)	Florel (3.9%) mL per 1 gallon	Collate (21.7%) mL per 1 gallon
250	21.7	3.9
500	43.4	7.8
1000	86.8	15.6



Ethephon (Florel[®] and Collate[®])

- The evolution of ethephon to ethylene increases as the spray solution pH increases above 4.5.
- Therefore, if spray solution pH is high, ethylene is released before it is absorbed by the plant.
- If spray solution pH is too low, potential for leaf phytotoxicity in some species.
- Spray solution pH is affected by the **alkalinity** of your carrier water.

Chemical and product names, product pH, and recommended final solution (PGR + initial carrier water) pH of the plant growth regulators.

Chemical	Product name/ distributor ¹	Product pH ²	Rec. final solution pH ³
Ancymidol	Abide™/a	8.5	5.5 – 6.5 ^a Not critical
Benzyladenine (BA)	Configure®/a	4 – 5 (1%)	5.0 – 6.5 ^b
Chlormequat chloride	Cycocel®/b	4.8 – 5.2	3.0 – 7.0 ^a
Daminozide	B-Nine® WSG/b	3.9 (1%)	4.0 – 8.0 ^c
Dikegulac-sodium	Augeo™/b	9.5	6.0 – 9.0 ^c
Ethephon	Florel®/c		<5.0 (4.0)^a
Fluprimidol	Topflor®/d	8.0 (1%)	5.5 – 8.5 ^d Not critical
gibberellic acid (GA)	Florgib®/a	3 – 4 (50% v/v sol.)	5.5 – 6.5 ^a
GA+BA	Fresco®/a	4.2 (1%)	5.5 – 6.5 ^a
Paclobutrazol	Piccolo®/a	7.7	4.0 – 9.0 ^a
Uniconazole	Concise®/a	6.26	5.5 – 7.0 ^b

¹ a=Fine Americas, Inc. Walnut Creek, CA; b=OHP, Inc. Mainland, PA; c=Southern Agricultural Insecticides, Inc. Palmetto, FL; d=SePRO Carmel, IN

² pH of product unless noted.

³ a=Yates et al. (2011), b= Fine Americas, Inc., c= OHP, Inc. Mainland, PA, d= SePRO Carmel, IN

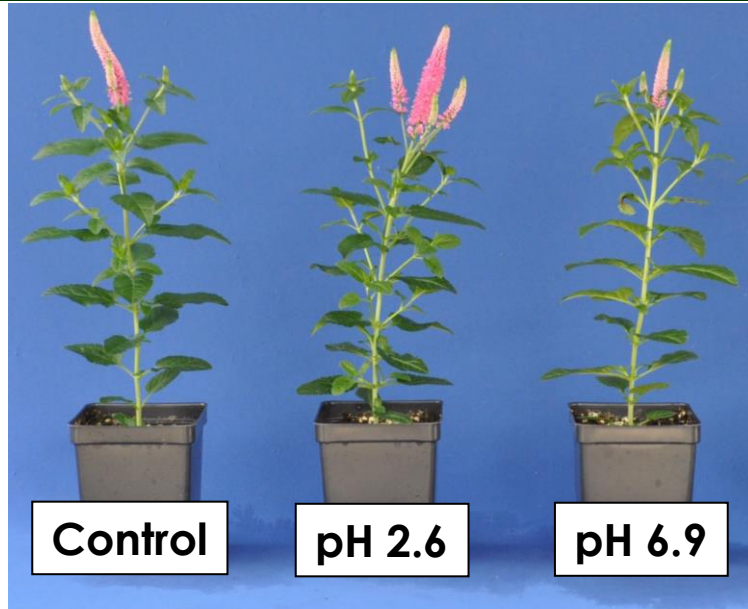
Plant damage with low pH



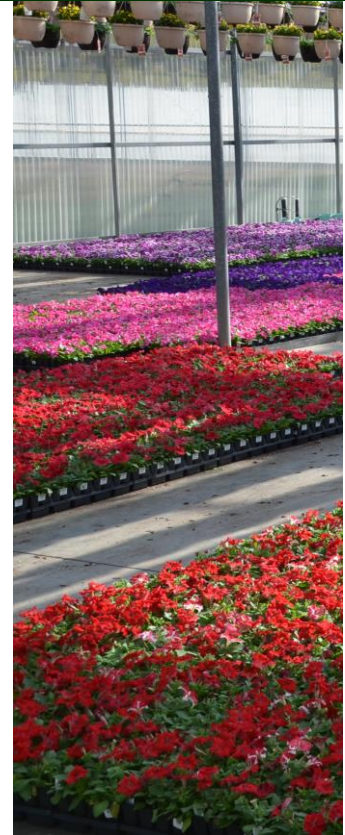
- Veronica 'First Love' 500 ppm Collate, pH 2.6
- Low alkalinity water can result in pH too low



Plant damage with low pH



- Veronica 'First Love' two weeks after 500 ppm Collate application
- No effect with high spray solution pH



Alkalinity

- Alkalinity is the capacity to resist pH change

Carrier Water + Ethephon

pH 7 Acidic

250 ppm Ethephon Spray Solution

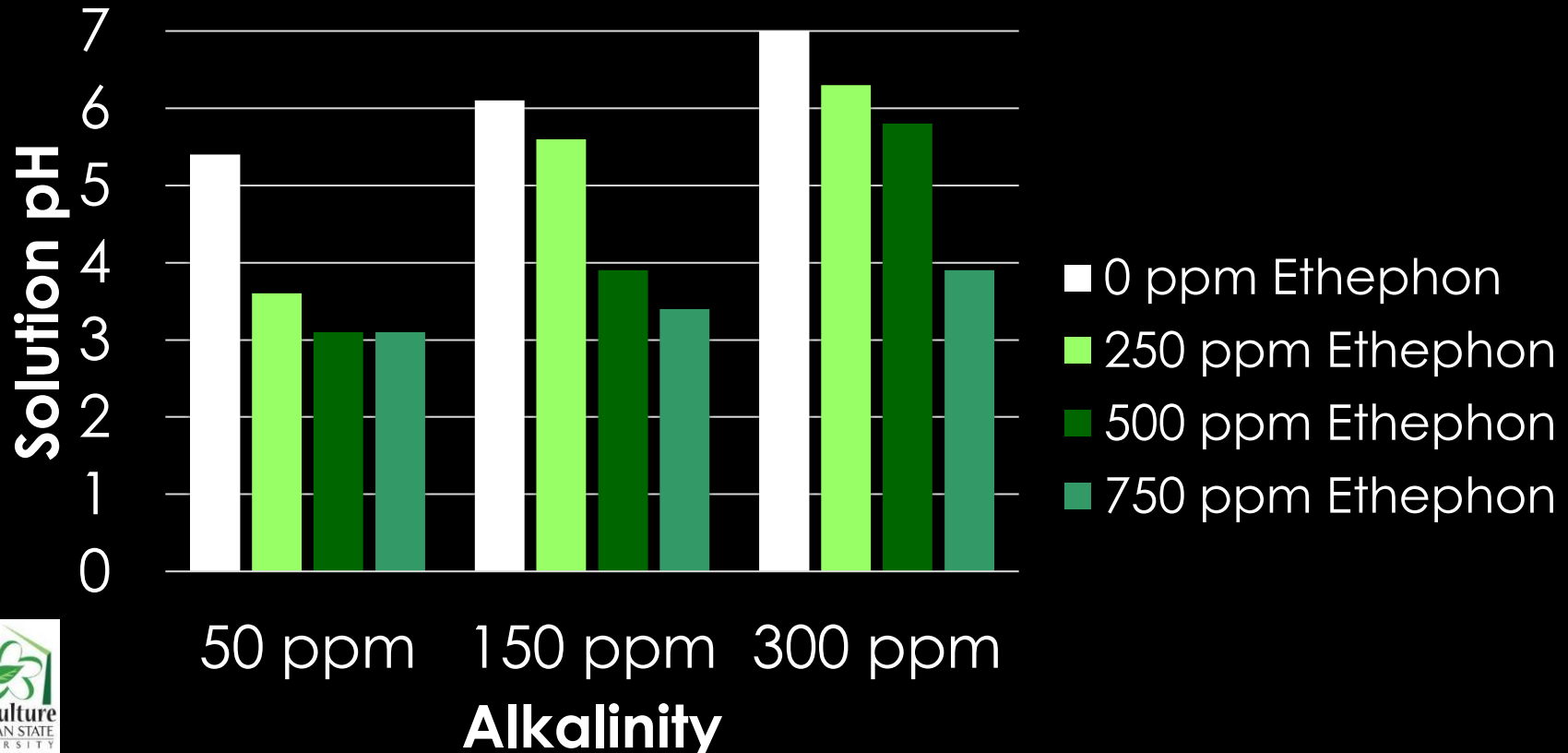
300 mg·L⁻¹ alkalinity
carrier water → pH 6.3

750 ppm Ethephon Spray Solution

300 mg·L⁻¹ alkalinity
carrier water → pH 3.9



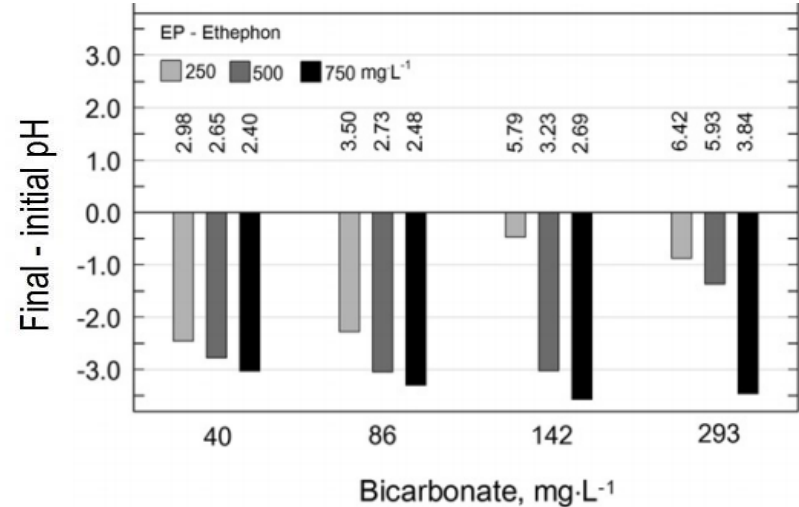
Solution pH changes



Does Water Alkalinity affect Ethephon Efficacy?

- Collate[®] and Florel[®] acidic
- Not sufficient when:
 - Chemical is used at low concentrations
 - Spray water has a high alkalinity

(Camberato et al., 2014)



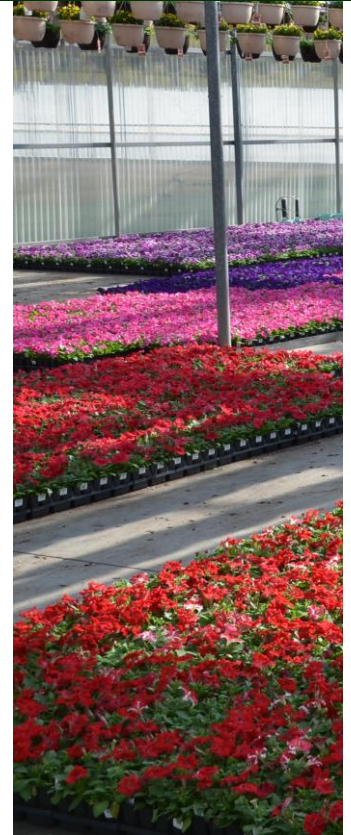
Does Water Alkalinity affect Ethephon Efficacy?

- Recommended application air temperature of 60 to 95 °F.
- At low temperatures ethephon breaks down slowly.
- At high temperatures ethephon breaks down quickly.

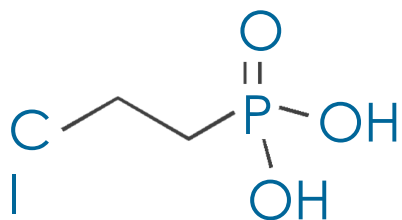


Objective

To determine if the efficacy of ethephon foliar sprays is affected by **carrier water alkalinity** and ambient **air temperature** at application



What Did We Do?



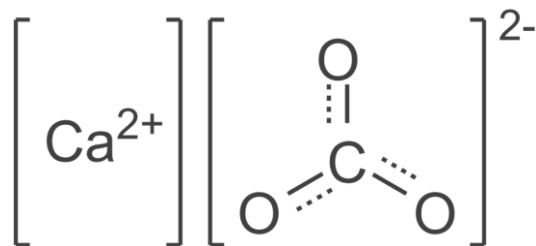
Ethephon

0 ppm

250 ppm

500 ppm

750 ppm



Alkalinity (CaCO₃⁻)

50 ppm

150 ppm

300 ppm



Temperature

79 °F

73 °F

68 °F

63 °F

57 °F

Plant Material



Petunia

Petunia ×hybrida

'Easy Wave Neon Rose'



Ivy geranium

Pelargonium ×peltatum

'Precision pink'



Verbena

Verbena peruviana

'Aztec Blue Velvet'

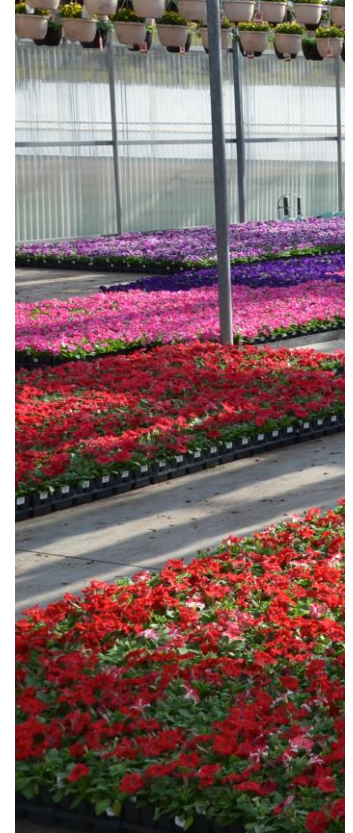
Grown at 68 °F and DLI of 10 mol·m⁻²·d⁻¹

Alkalinity and Air Temperature Treatments

- Alkalinity of tap water adjusted with sulfuric acid
- Air temperature at application was changed 2 hours prior to spray application for 24 h
(it takes ~12 to 16 h to fully absorb ethephon)



Methods





High Alkalinity Reduces Efficacy

Alkalinity (ppm)

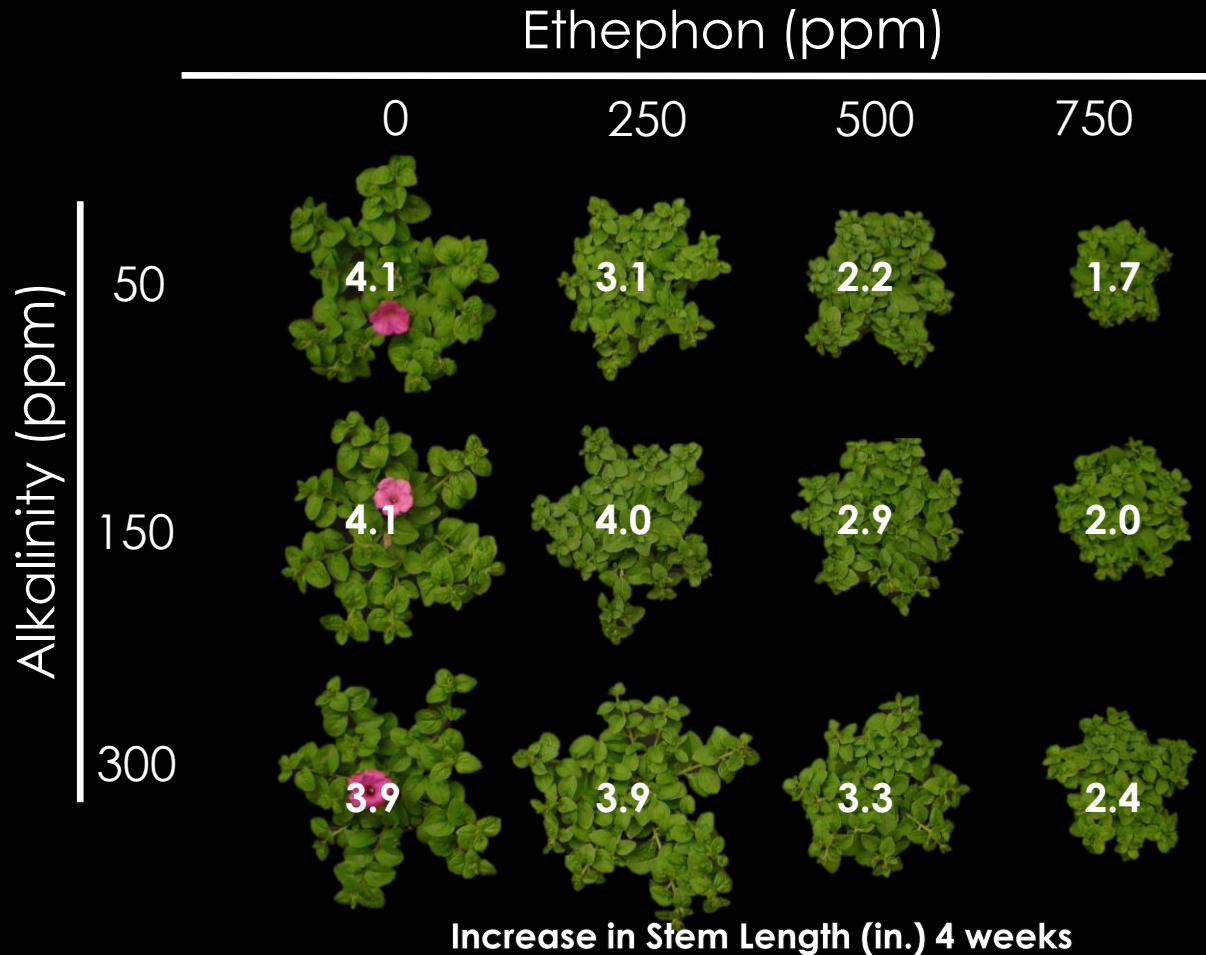
50

150

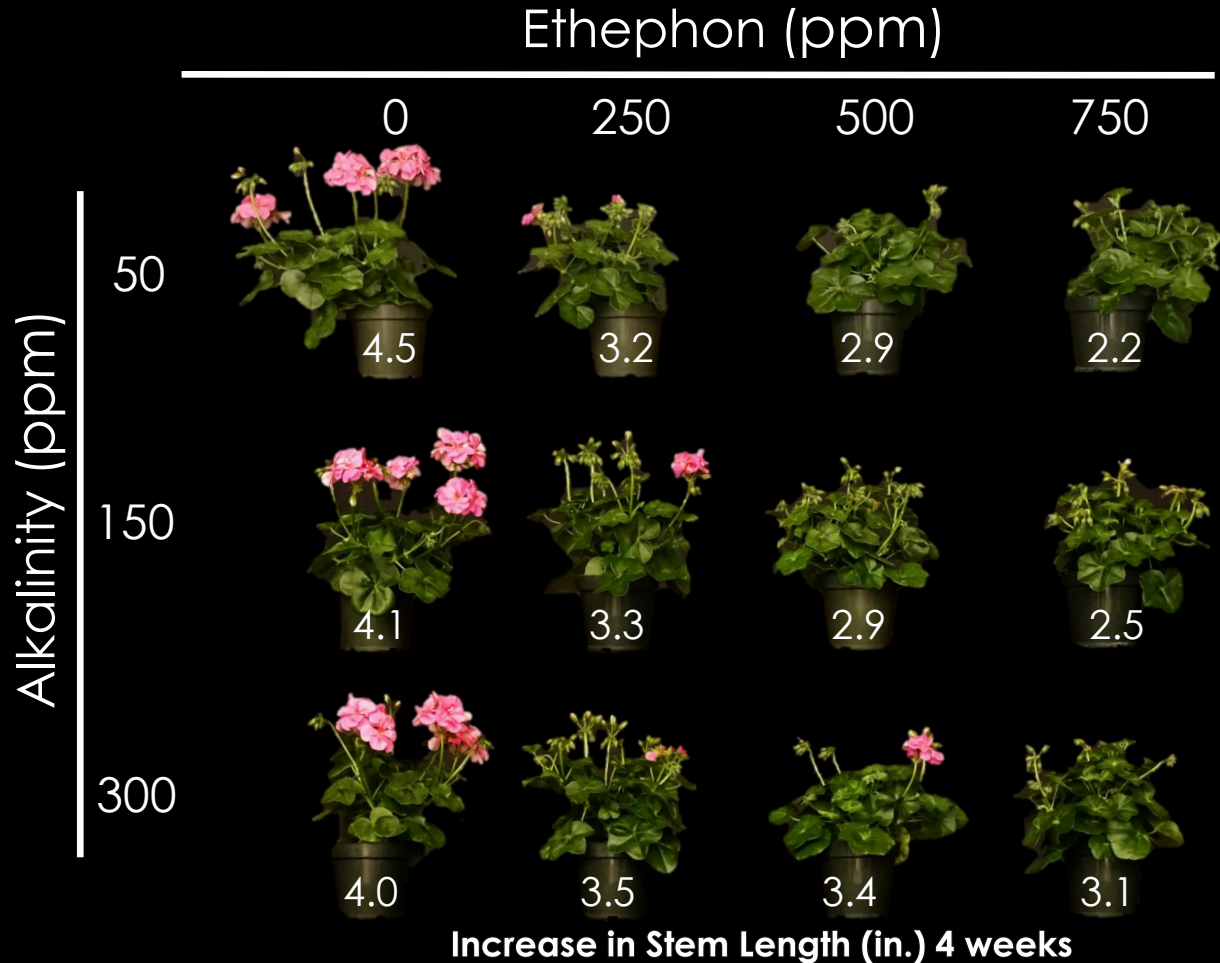
300



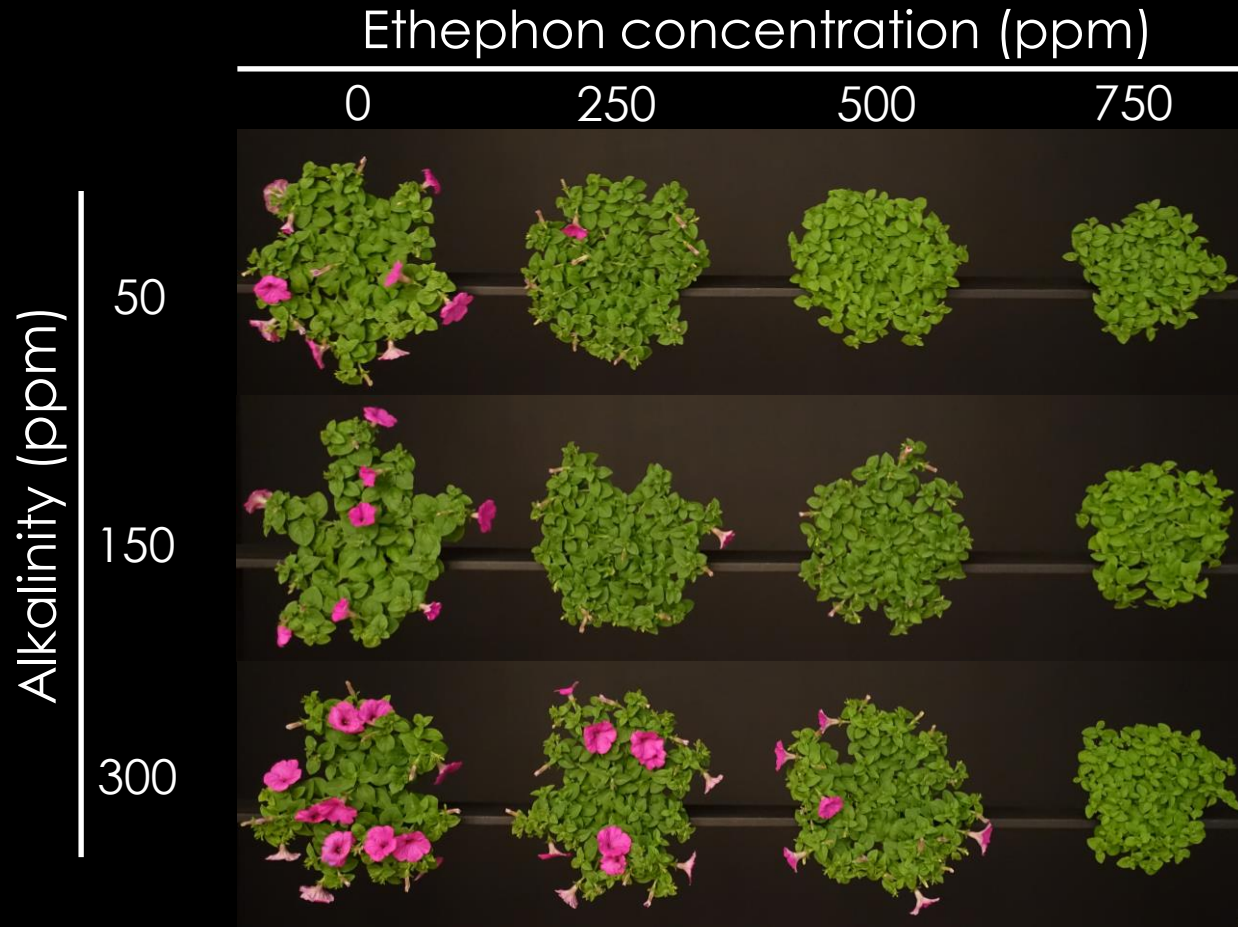
Alkalinity and ethephon concentration interact



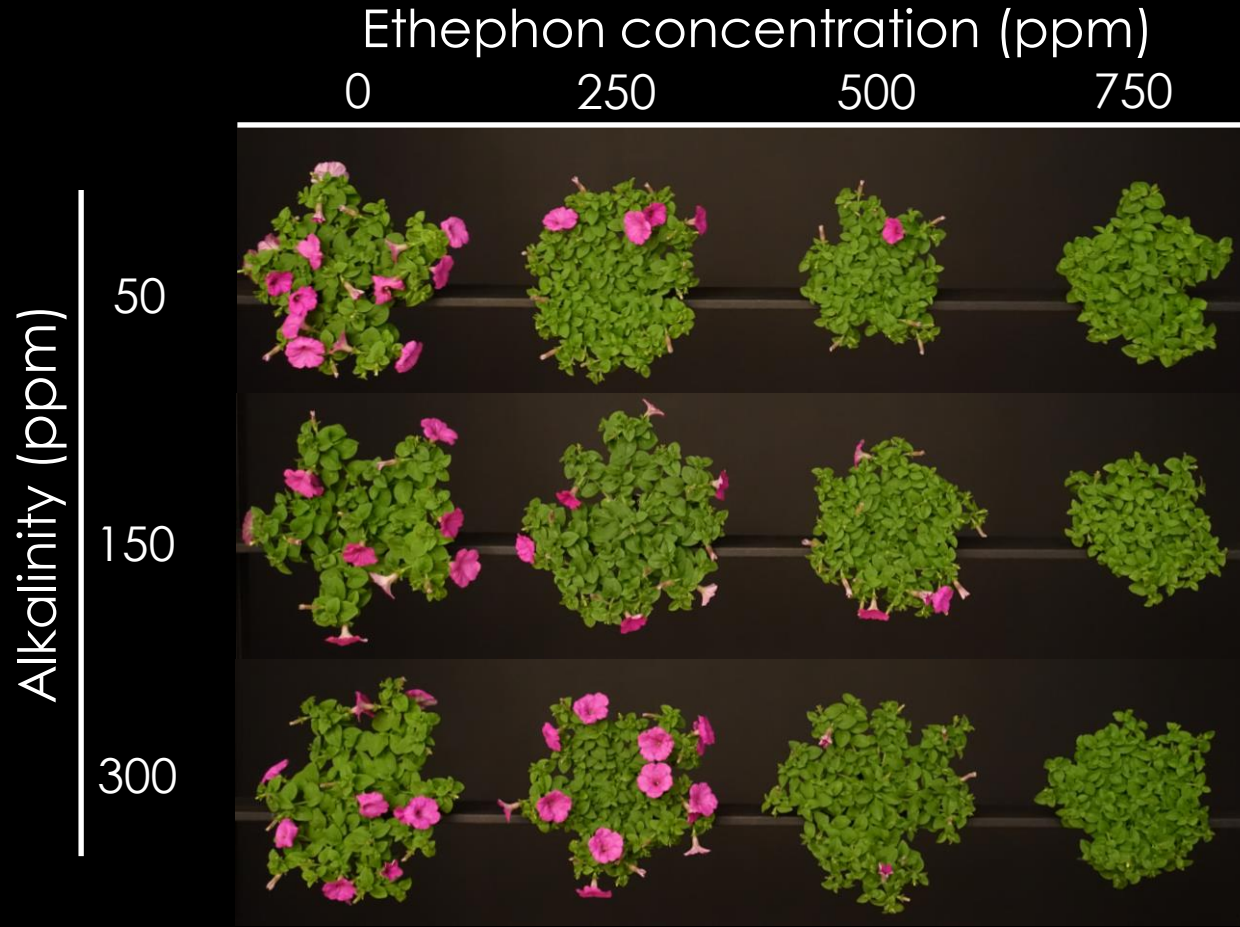
Alkalinity and ethephon concentration interact



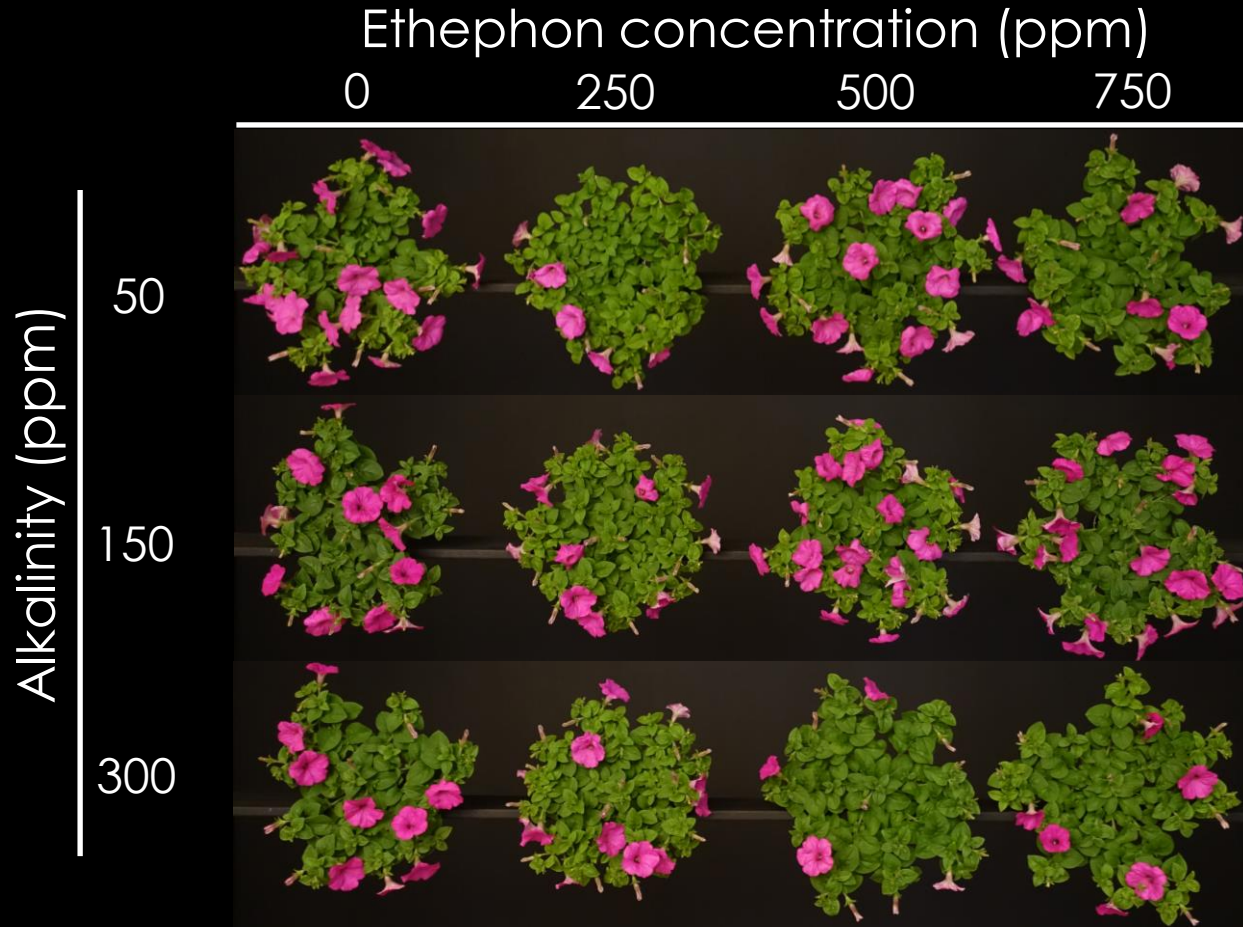
Petunia 'Easy Wave Neon Rose' 57 °F












Petunia 'Easy Wave Neon Rose' 68 °F



Petunia 'Easy Wave Neon Rose' 79 °F



Ambient temperature at application influences efficacy

	57	63	68	73	79 °F
					
Days to flower	45	45	46	45	41
Branches (no.)	63	64	67	67	48
					
Days to flower	51	49	49	51	40
Branches (no.)	7	6	7	7	5

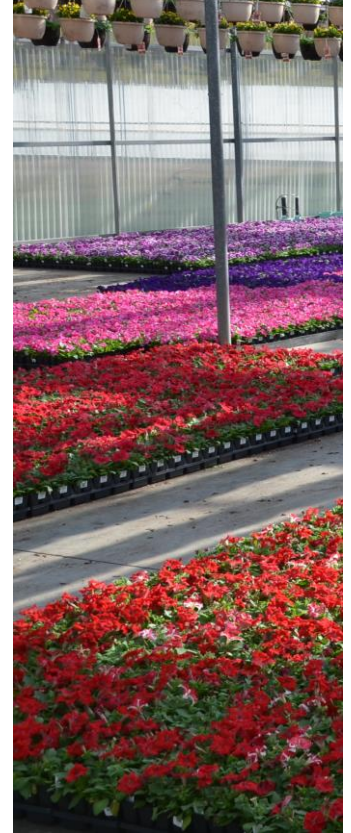
Ethephon Tips

- If your carrier water has high alkalinity, add a buffering solution to reduce pH before adding ethephon to the spray tank.
 - acid (i.e., sulfuric acid)
 - adjuvant (i.e., Indicate 5)
- Apply ethephon when greenhouse temperatures are below 75 °F
- Maintain high relative humidity or VPD of 0.7 kPa.
- Always conduct in-house trials.



Ethephon Tips

- Allow the solution to dry slowly over 4 hours to enhance uptake.
- Relative absorption time of foliar applications is 12 to 16 hours.
- Species and cultivars vary in response; thus you have to conduct your own rate trials.



Ethephon Tips

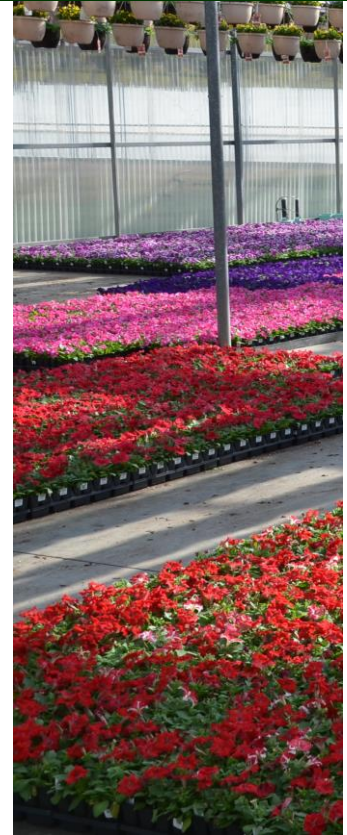
- Must manage application timing to avoid flowering delay (allow 6 to 8 weeks prior to desired market date).



Brian Whipker, NC State

Ethephon Tips

- Ethephon is a minor eye and skin irritant:
 - It has a longer restricted entry interval (REI) of 48 hours.
 - In addition, eye protection is required, along with protective gloves, coveralls, apron, shoes and headgear for overhead applications.



Ethephon Tips

- Avoid applications to stressed plants:
 - Ethylene is a natural plant hormone that influences fruit ripening, senescence, branching and growth.
 - Ethephon can enhance the stress.



Brian Whipker, NC State



Evaluating PGRs to Promote Branching on Finished Plants

Materials and Methods

Vegetative rooted cuttings:

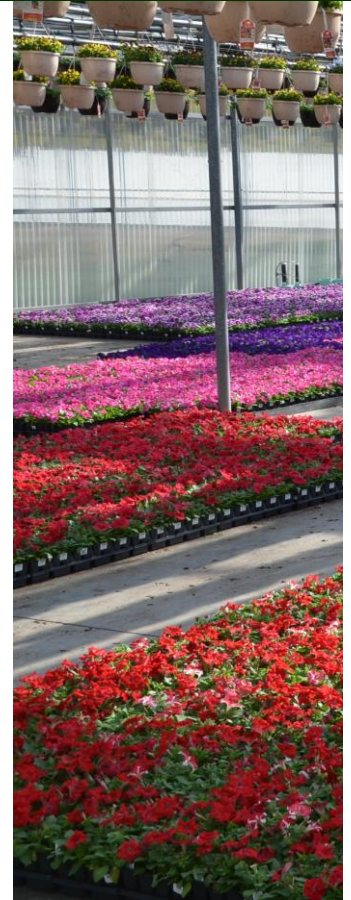
- Cyperus 'Baby Moses'
- Celosia 'Dark Purple'
- Euphorbia 'Breathless White'
- Scaevola 'Sallyfun Blue'



Materials and Methods

Plant Growth Regulators:

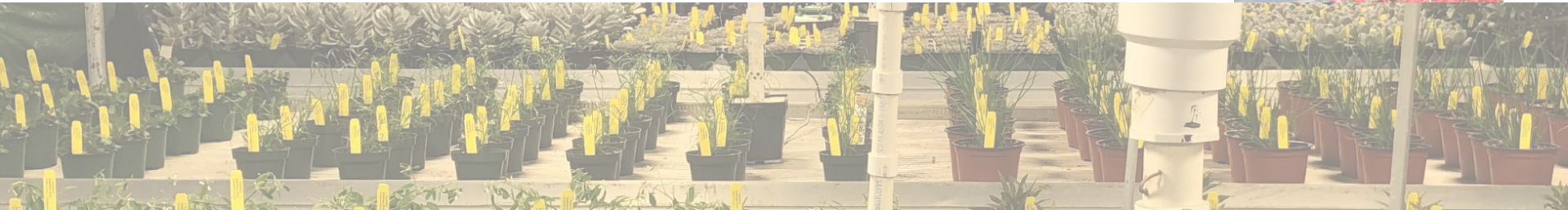
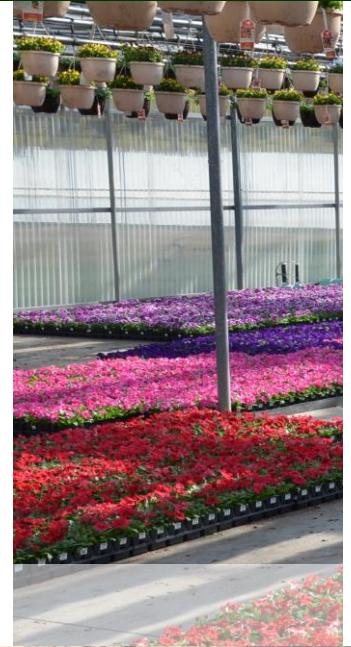
- Crest (0.01% kinetin, 0.005% IBA and GA_3)
 - Label rate: 1 oz/4 gal.
- Configure (2% 6-BA)
 - Label rate: 50-500 ppm



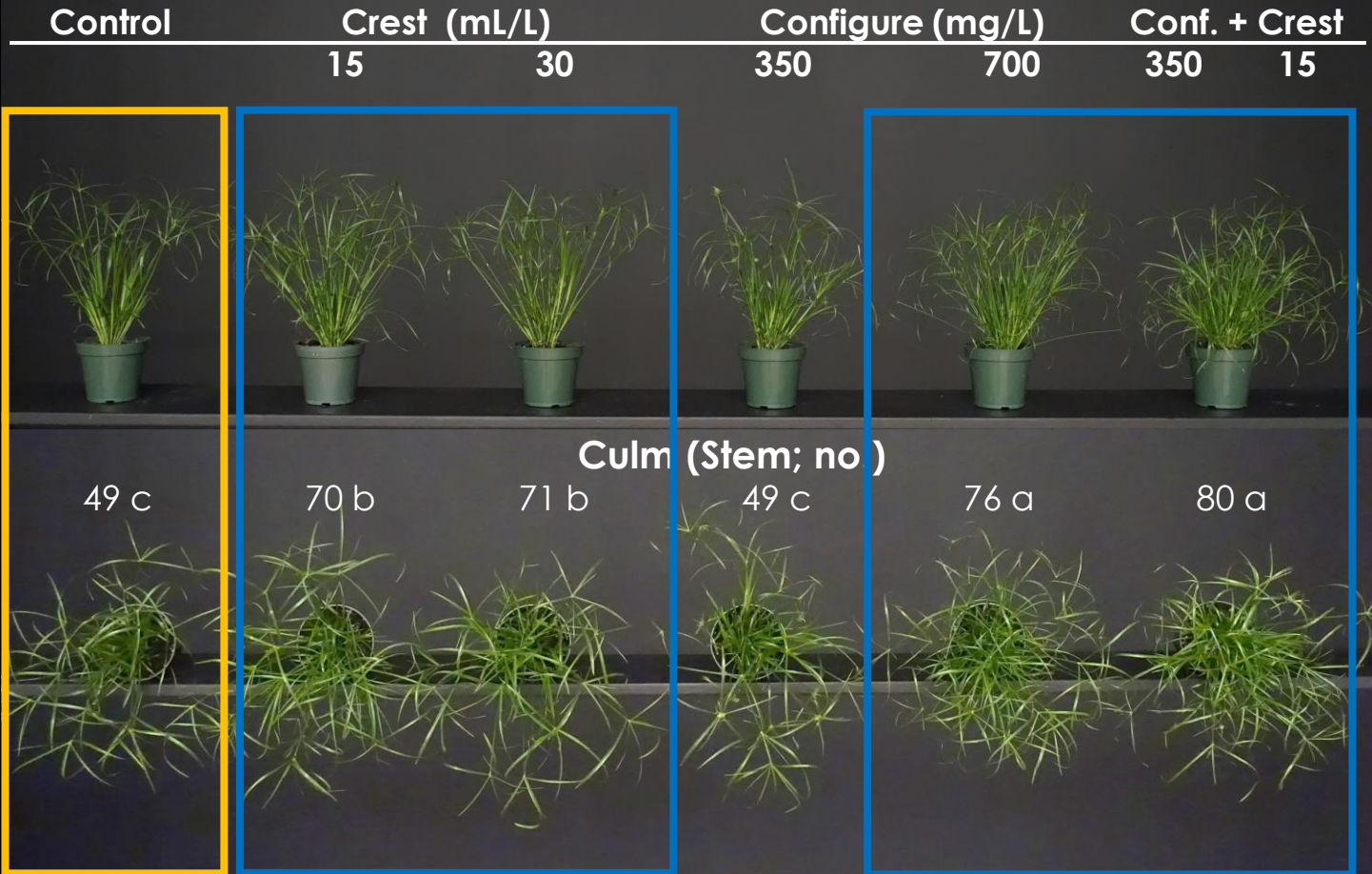
Materials and Methods

Treatments:

1. Control
2. Crest 15 mL·L⁻¹ at 0.2 L·m⁻² spray
3. Crest 30 mL·L⁻¹ at 0.2 L·m⁻² spray
4. Configure 350 ppm spray
5. Configure 700 ppm spray
6. Crest 15.6 mL·L⁻¹ at 0.2 L·m⁻² + Configure 350 ppm spray



Cyprus 'Baby Moses'



Celosia 'Dark Purple'

Control

Crest (mL/L)

Configure (mg/L)

Conf. + Crest

15

30

350

700

350

15



Branches (no.)

35 b

31 b

33 b

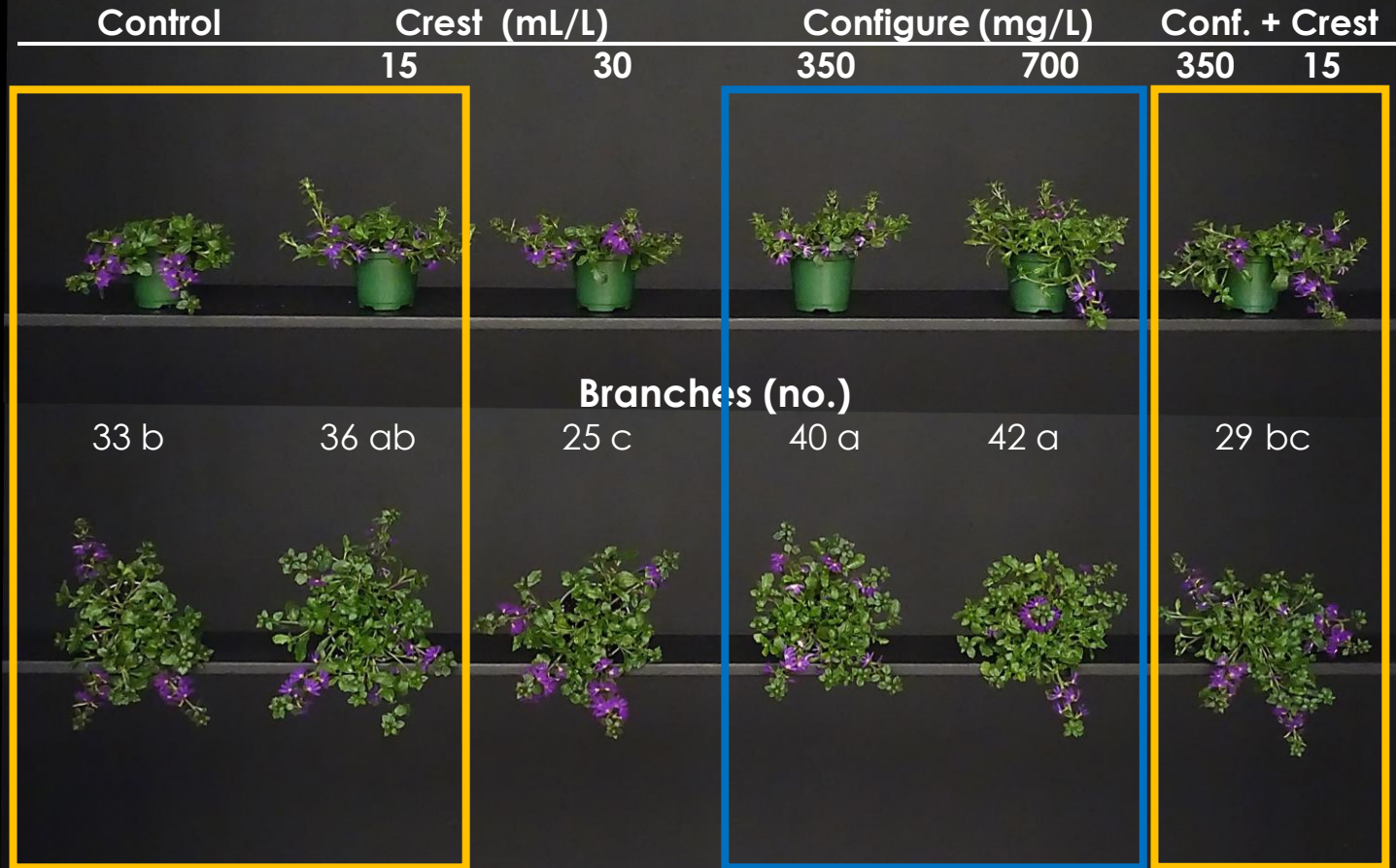
55 a

46 a















47 a



Scaevola 'Sallyfun Blue'



Euphorbia 'Breathless White'

Control	Crest (mL/L)		Configure (mg/L)		Conf. + Crest	
	15	30	350	700	350	15
						
100 b	64 c	82 c	70 c	71 c	122 a	
						

Take Home Message

- **Cyperus ‘Baby Moses’**

- Crest (15 or 30 mg/L), Configure (700 ppm), or Crest (15 mg/L) + Configure (350 ppm)
 - Increased culms
 - Filled in container 2 weeks earlier

- **Celosia ‘Dark Purple’**

- Configure (350 or 700 ppm), or Crest (15 mg/L) + Configure (350 ppm)
 - Increased branching
 - More compact
 - Increased foliage color



Take Home Message

- **Scaevola 'Sallyfun Blue'**

- Configure (350 or 700 ppm)
 - Increased branching
- Crest (30 mg/L)
 - Reduced branching
- Crest (15 mg/L) or Crest (15 mg/L) + Configure (350 ppm)
 - Increased extension growth



Take Home Message

- **Euphorbia 'Breathless White'**
 - Configure (350 or 700 ppm)
 - Delayed flowering and smaller bracts
 - Crest (15 or 30 mg/L) or Configure (350 or 700 ppm)
 - Reduced branching
 - Crest (15 mg/L) + Configure (350 ppm)
 - More compact
 - More branching



Materials and Methods

- *Angelonia angustifolia* 'Big Indigo'
- *Calylophus* hybrid 'Ladybird Sunglow'
- *Cyperus papyrus* 'King Tut'
- *Lantana camara* 'Trailing Lavender'
- *Petunia* hybrid 'Night Sky'
- *Pelargonium peltatum* 'Light Lavender'
- *Verbena rigida* 'Cake Pops'



Materials and Methods

Plant Growth Regulators:

- Collate (21.7% Ethephon)
 - Label rate: 300-500 ppm
- Configure (2% 6-BA)
 - Label rate: 50-500 ppm
- Crest (0.01% kinetin, 0.005% IBA and GA₃)
 - Label rate: 1 oz/4 gal.
- Fresco (1.8% GA + 1.8% BA)
 - Label rate: 1/1 to 100/100 ppm



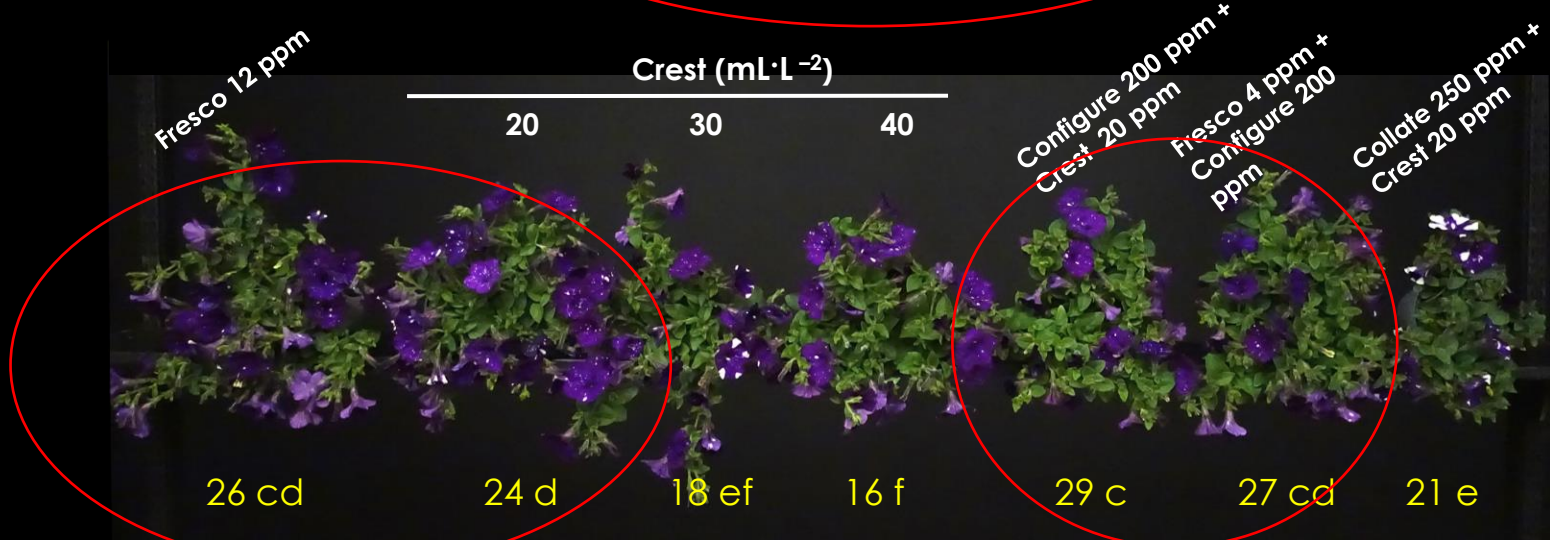
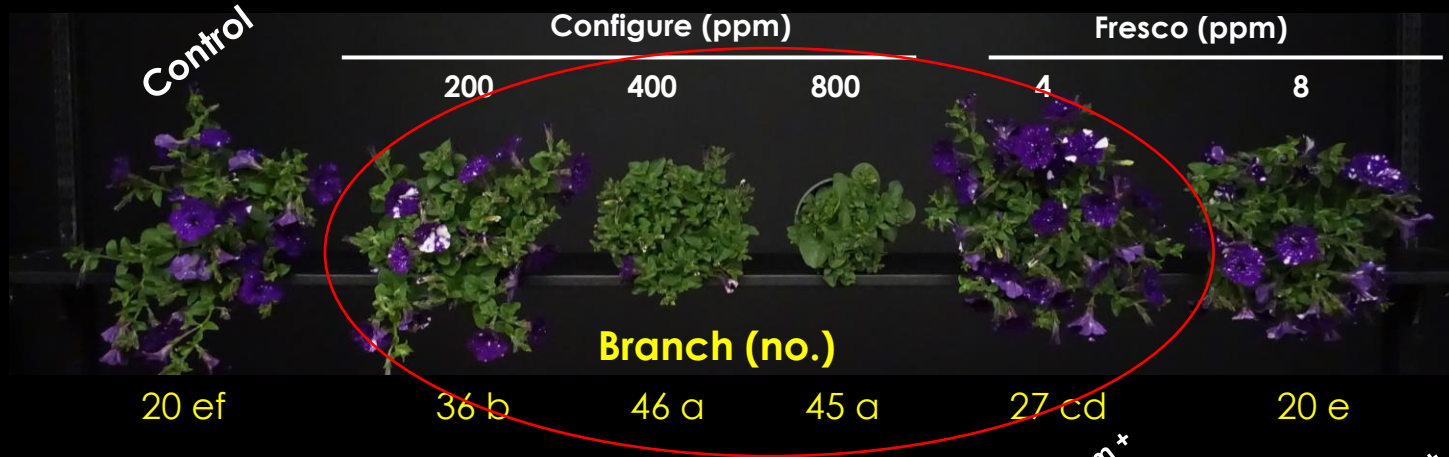
Materials and Methods

Treatments (2 wks after transplant):

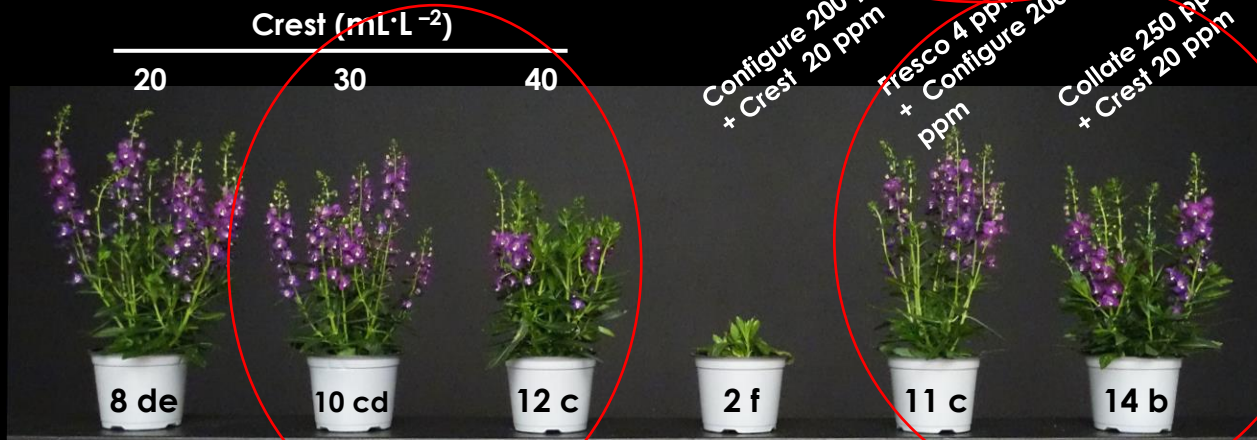
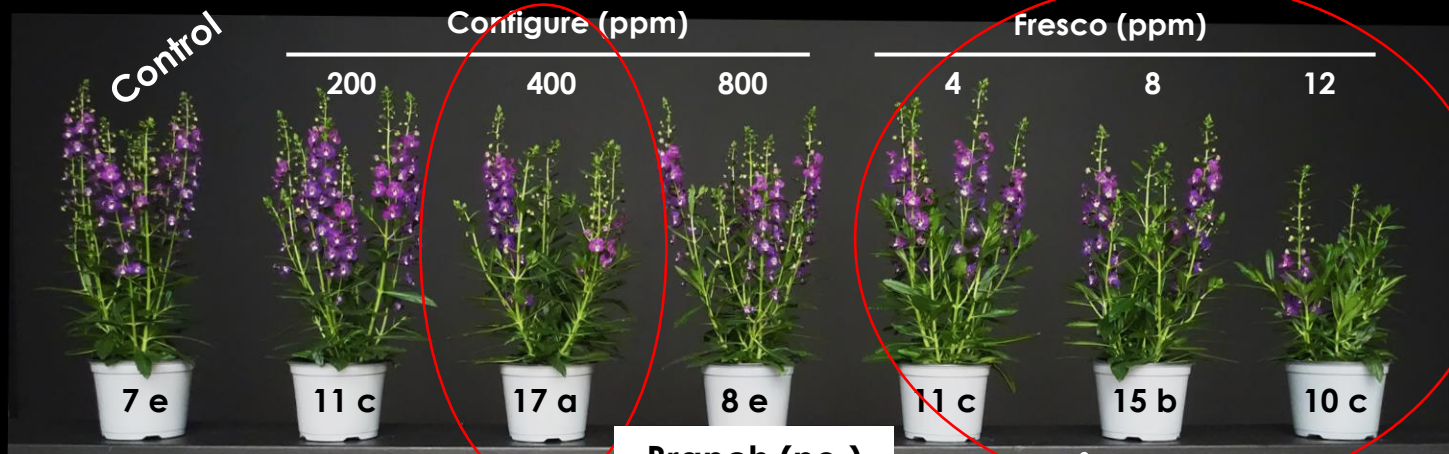
- 1) Untreated control
- 2) 200 ppm benzyladenine, BA (Configure)
- 3) 400 ppm benzyladenine, BA (Configure)
- 4) 800 ppm benzyladenine, BA (Configure)
- 5) 4 ppm BA + GA₄₊₇ (Fresco)
- 6) 8 ppm BA + GA₄₊₇ (Fresco)
- 7) 12 ppm BA + GA₄₊₇ (Fresco)
- 8) 20 mg/L kinetin + IBA + GA (Crest)
- 9) 30 mg/L kinetin + IBA + GA (Crest)
- 10) 40 mg/L kinetin + IBA + GA (Crest)
- 11) 200 ppm Configure + 20 mg/L Crest
- 12) 4 ppm Fresco + 200 ppm Configure
- 13) 250 ppm Collate + 20 mg/L Crest



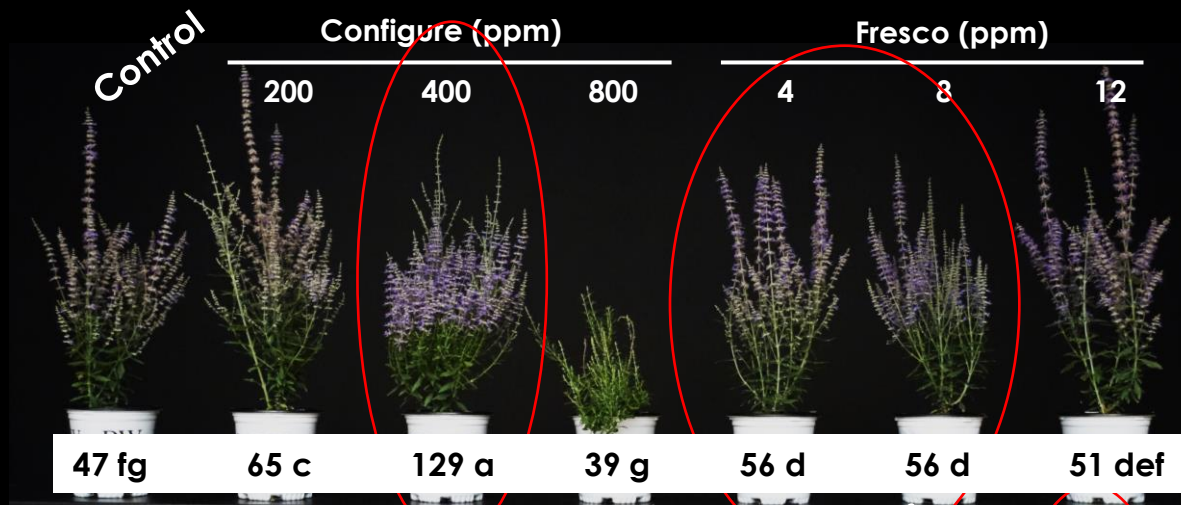
Petunia hybrid 'Night Sky'



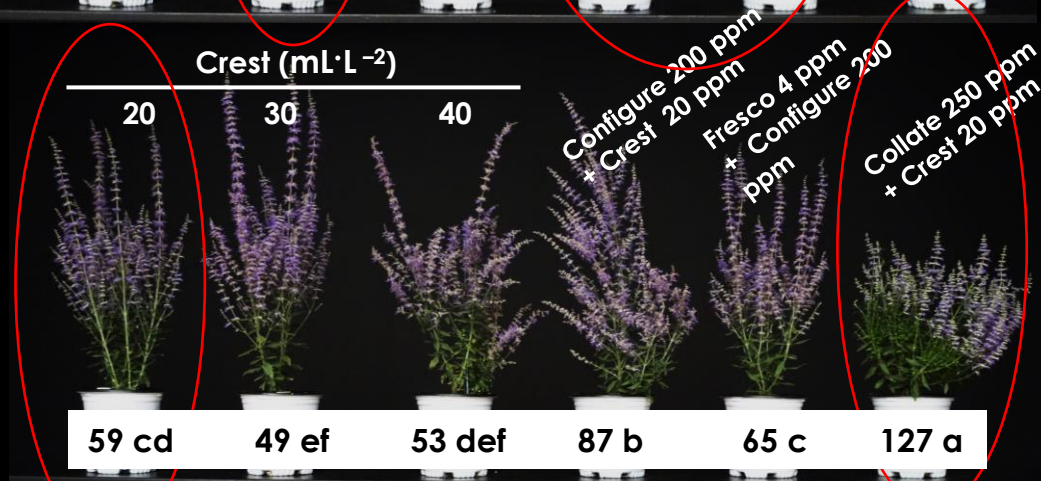
Angelonia angustifolia 'Big Indigo'



Perovskia atriplicifolia 'Sage Advice'



Branch (no.)



Take Home Message

- Configure promoted branching:
 - **400 ppm:**
 - Angelonia**
 - Calylophus**
 - Geranium**
 - Petunia**
 - Russian sage
 - **800 ppm:**
 - Papyrus



**delay in flowering or compact growth



Take Home Message

- Fresco or Fascination promoted branching:

- **4 ppm:**

- Angelonia
- Calylophus*
- Geranium
- Papyrus
- Petunia*
- Russian sage

- **8 ppm:**

- Angelonia
- Geranium
- Papyrus
- Russian sage**

- **12 ppm:**

- Angelonia**
- Geranium**



or



*slight increase in the size of the plant

** Plants more compact

Take Home Message

- Crest promoted branching:
 - **20 ppm:**
 - Petunia*
 - Russian sage
 - **30 ppm:**
 - Angelonia**
 - Papyrus**
 - **40 ppm:**
 - Angelonia**
 - Papyrus**



** Plants more compact

Take Home Message

- 200 ppm Configure + 20 mg/L Crest promoted branching:
 - Petunia
 - Geranium



+



Take Home Message

- 4 ppm Fresco + 200 ppm Configure:
 - Angelonia
 - Calylophus
 - Cyperus
 - Petunia
 - Geranium



+



Take Home Message

- 250 ppm Collate or Florel + 20 mg/L Crest:
 - Angelonia
 - Calylophus
 - Cyperus
 - Geranium
 - Russian Sage



or



+



Acknowledgments



United States Department of Agriculture
National Institute of Food and Agriculture

