Manipulating light and other factors in the nursery to improve budbreak and growth during winter




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During the winter, the citrus nursery production cycle is considerably slowed.

In November, December and January, citrus nurseries typically reduce budding of new trees due to low temperature and short day.

Our project was aimed to characterize the factors associated with the slowing of nursery production in winter, and to identify ways to improve winter nursery production.

Hours of light per day

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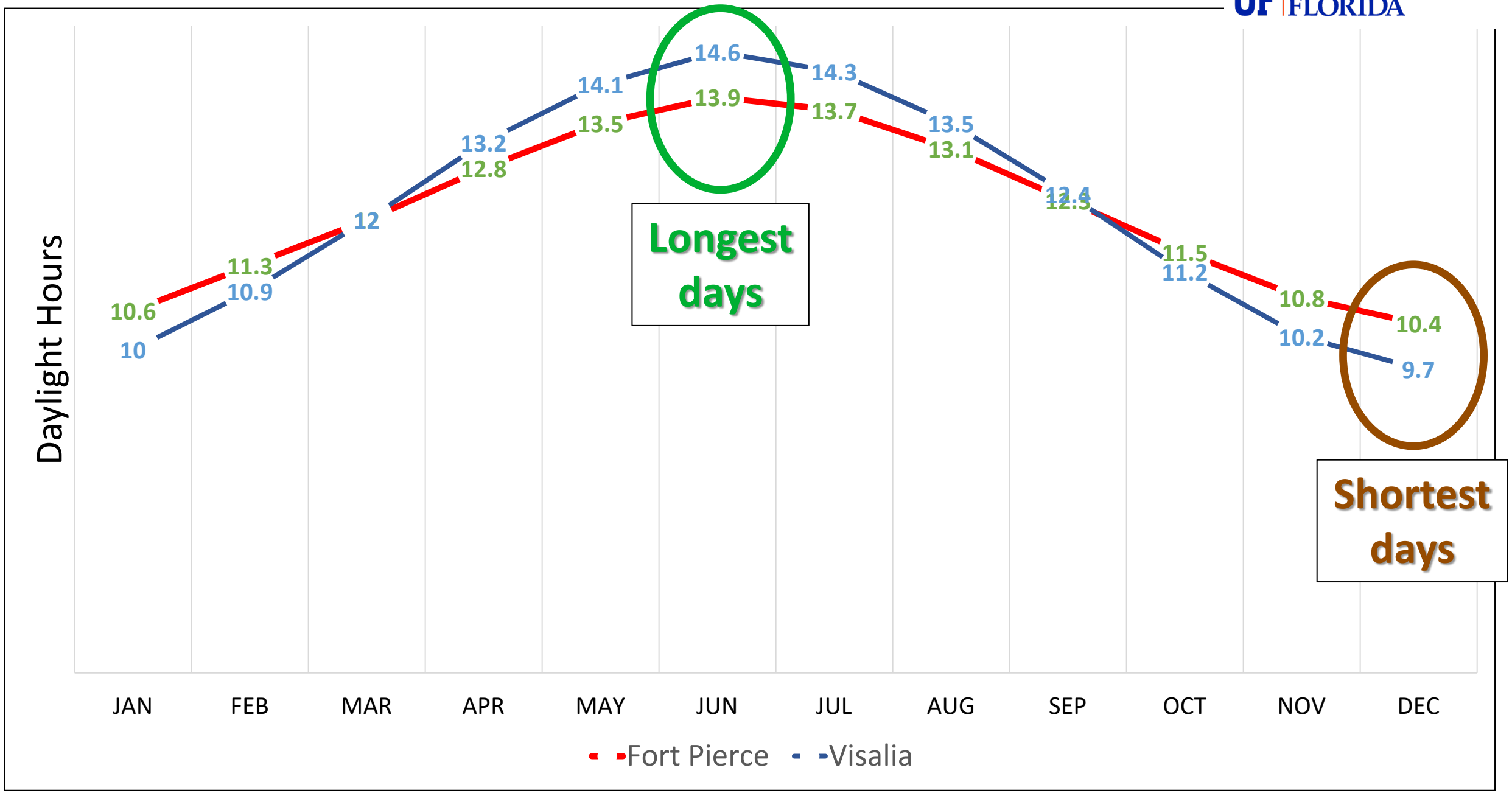

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Improving Winter Growth in the Citrus Nursery with LED and HPS Supplemental Lighting

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Additional index words. Cleopatra, cutting, day length, micropropagation, nursery, photoperiod, rootstock, seedling, sour orange, sweet orange, 'US-1516', 'US-812', 'US-897', 'US-942'

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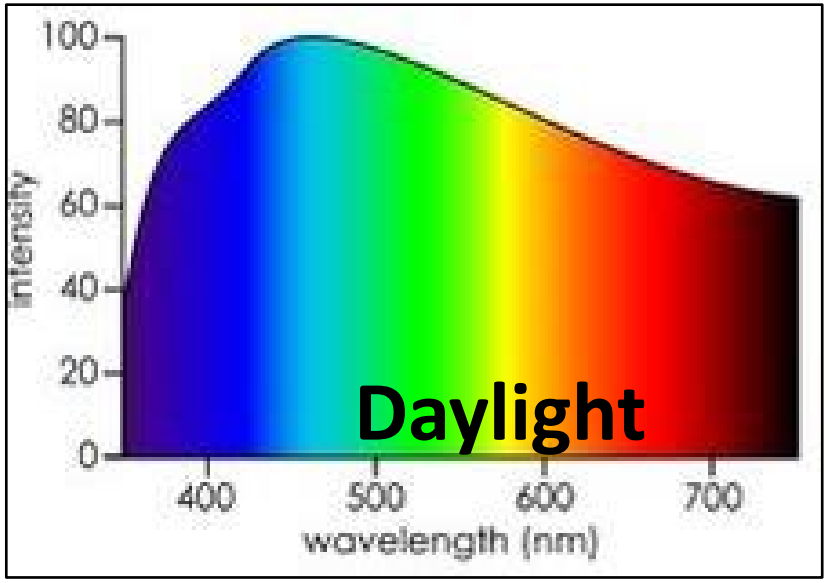

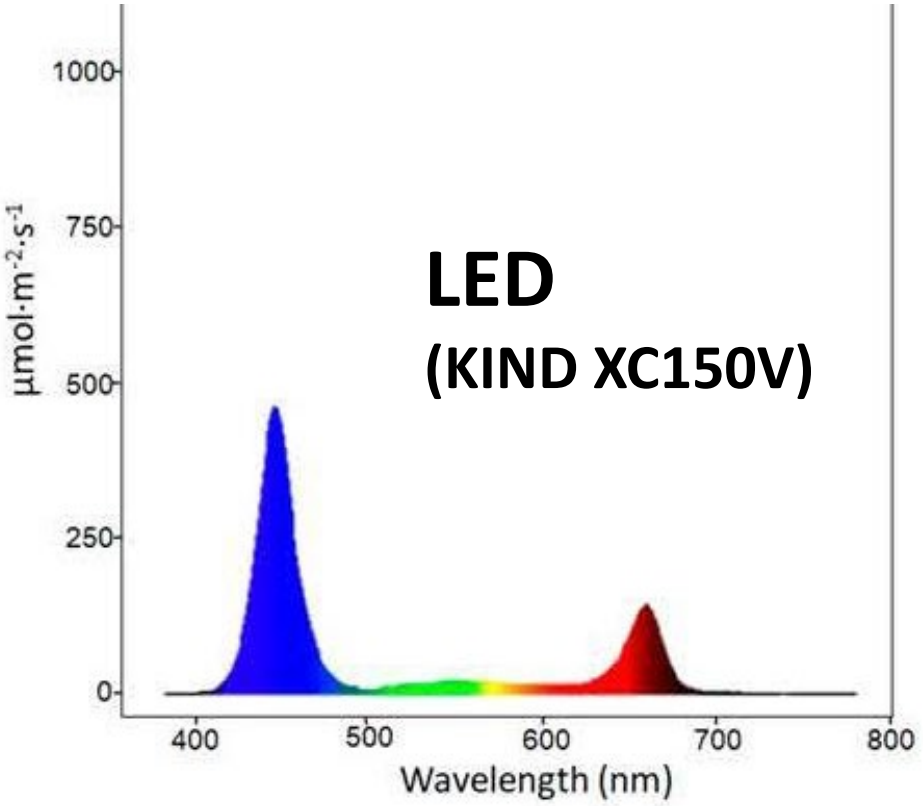

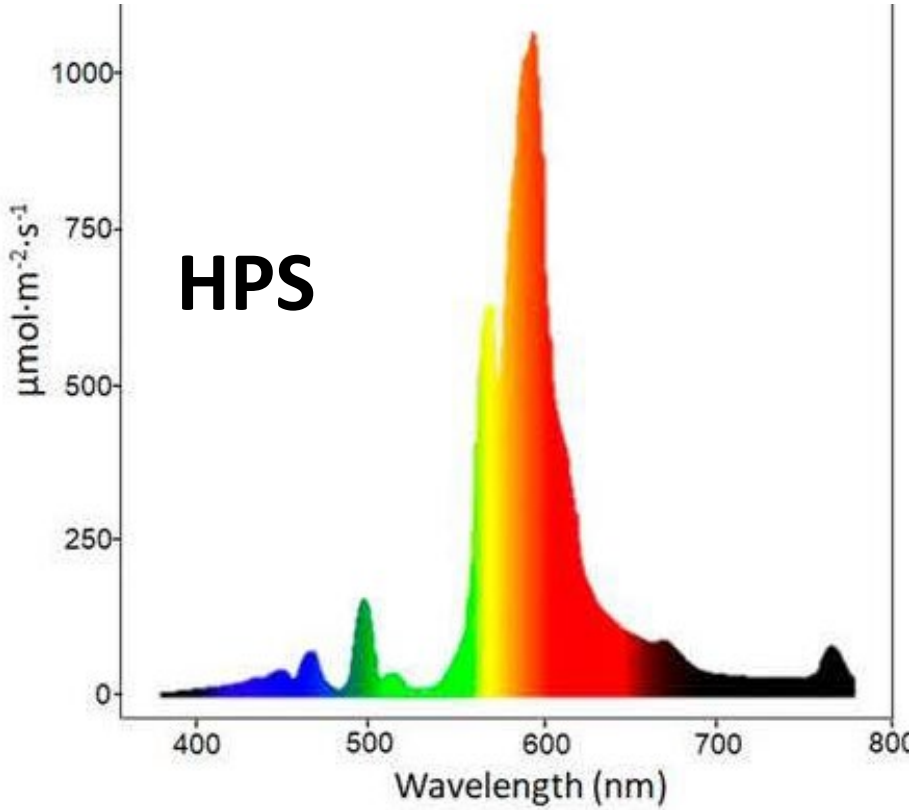

CCNB Project Objectives – over 3 winter seasons

Objective 1. Evaluate budbreak and growth effects from supplemental heat, extended daylength, and night interruption.

Objective 2. Evaluate budbreak and growth effects from light and temperature preconditioning.

Objective 3. Evaluate influence of spectral quality and intensity on budbreak and growth effects.

Objective 4. Evaluate influence of BA application on budbreak and growth effects.

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Heliospectra Elixia LED Variable Spectrum Light: Independent control of Red, Blue, White, and Infrared spectra

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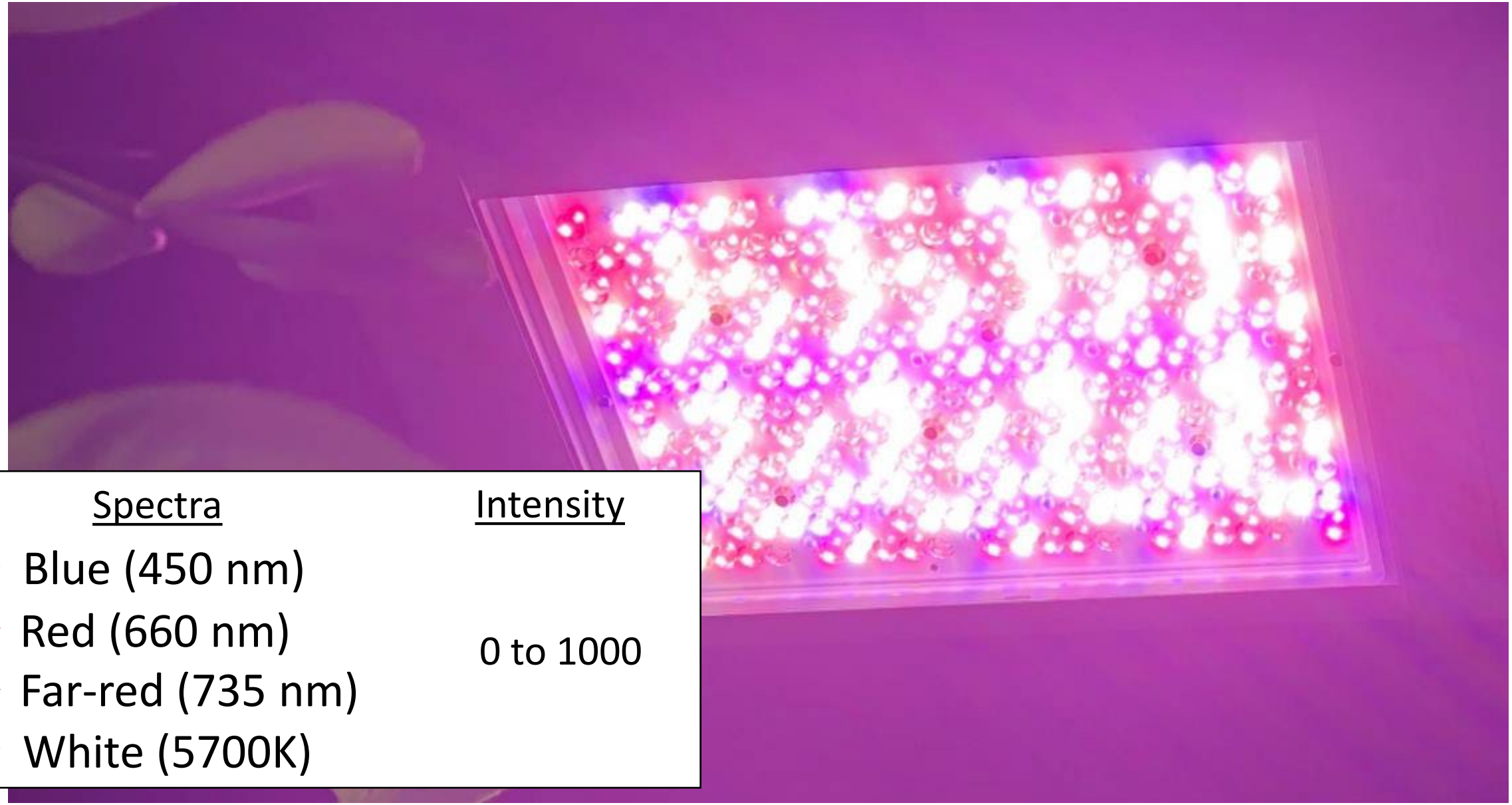

Spectra	Intensity
➡ Blue (450 nm)	
➡ Red (660 nm)	0 to 1000
➡ Far-red (735 nm)	
⇨ White (5700K)	

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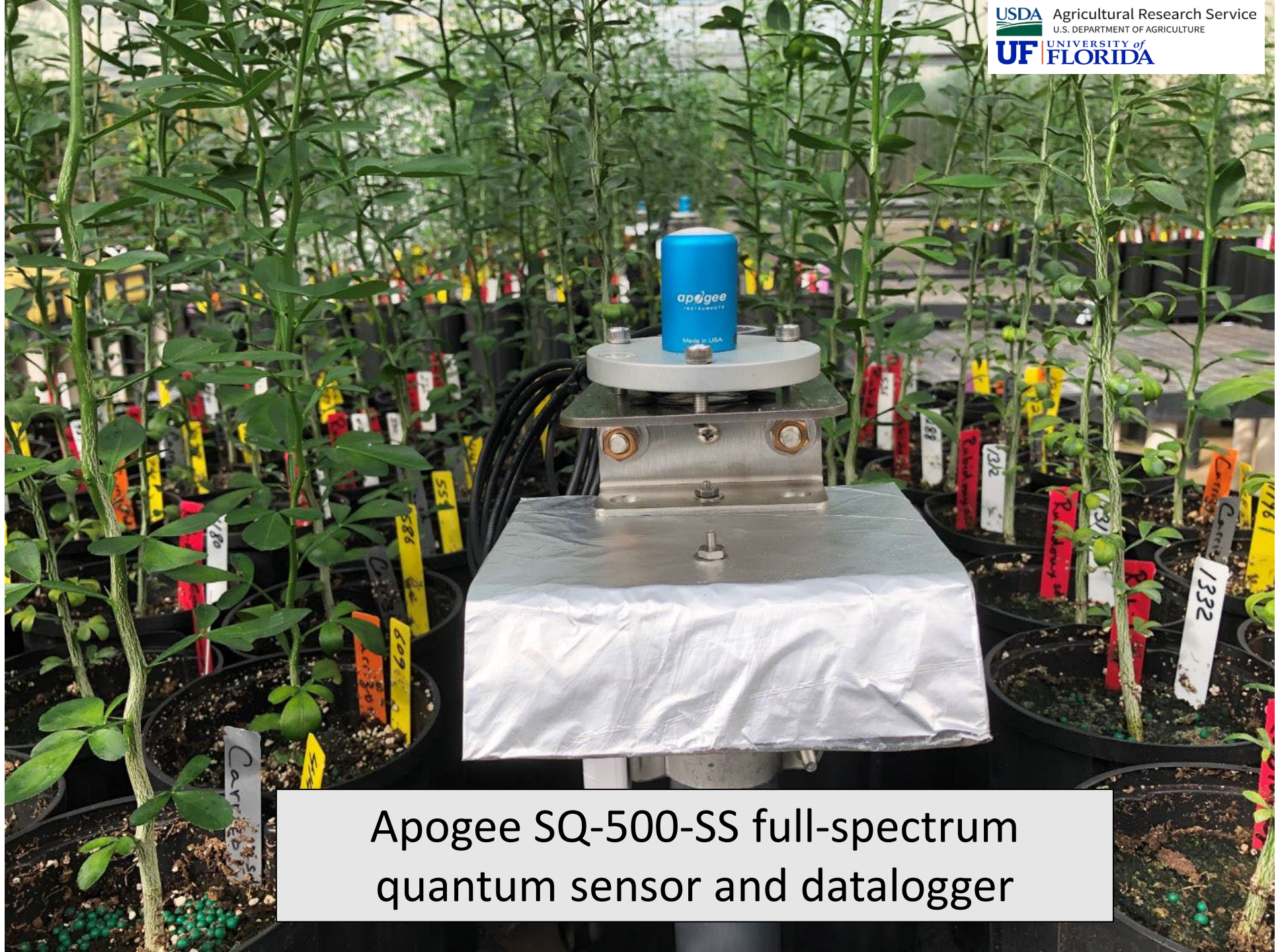

Apogee SQ-500-SS full-spectrum quantum sensor and datalogger

Temperature sensor and datalogger MX2203

PG100N Spectrometer

Project Objectives – Year 1

Objective 1. Evaluate budbreak and growth effects from supplemental heat, extended daylength, and night interruption.

Objective 2. Evaluate budbreak and growth effects from light and temperature preconditioning.

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MDPI

Article

Increasing Sweet Orange Growth in the Winter Nursery with Supplemental Light and Heating

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Abstract: In the winter season, citrus nursery production faces challenges including shorter days, lower light levels, and lower temperatures that delay vegetative budbreak and scion shoot growth. With the goal of improving the production cycle in the citrus nursery, we investigated the effect of supplemental LED light on the production of bud-grafted citrus trees during short winter days. Three experiments were conducted under different temperature conditions. "Washington" Navel sweet orange (*Citrus sinensis*) was budded on Carrizo citrange (*C. sinensis* × *Poncirus trifoliata*) and Rubidoux trifoliate (*P. trifoliata*) rootstocks in early December. Light treatments included no

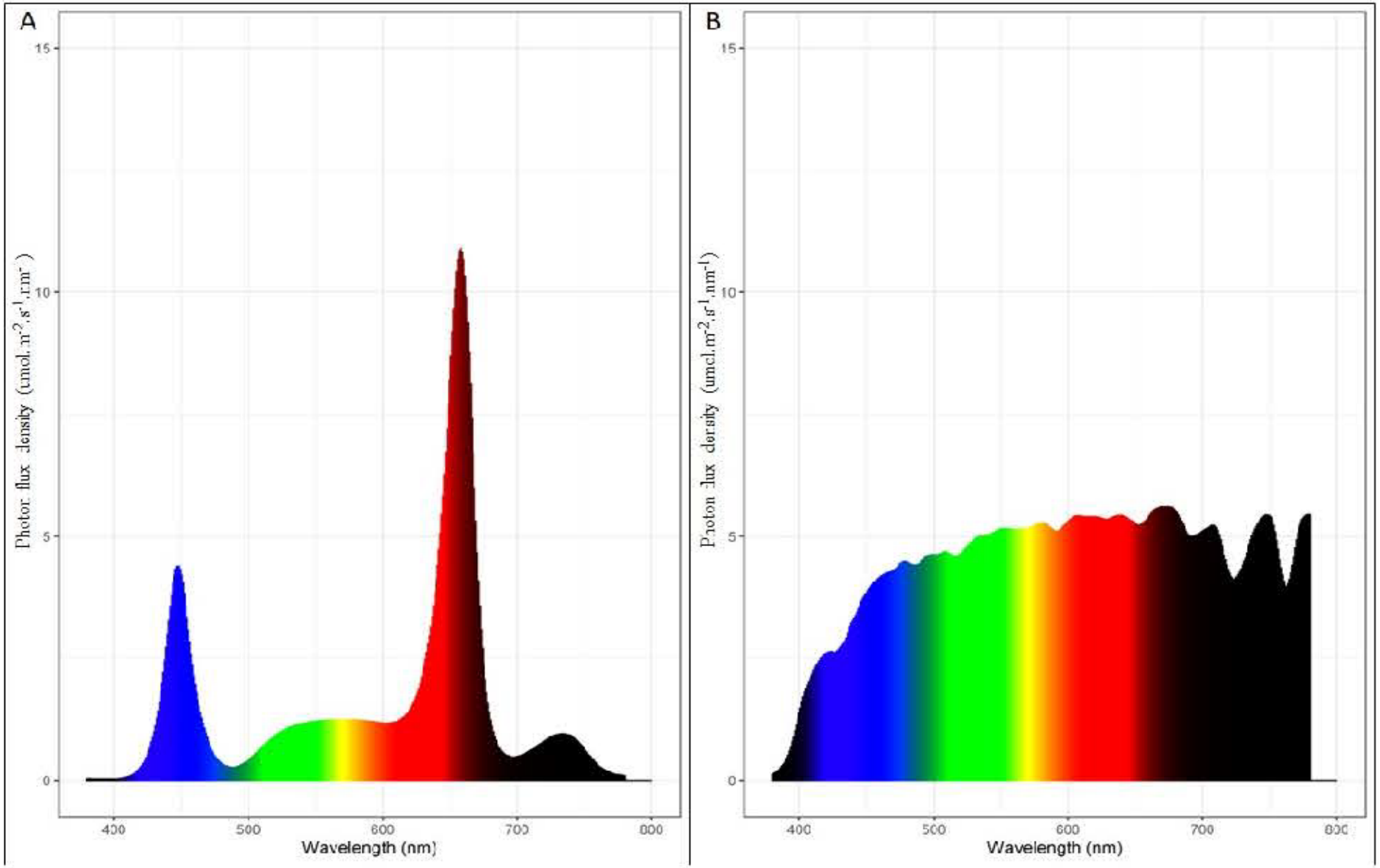

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Figure 1. LED light spectra at night (**A**), 110 cm below the light fixture and at noon in the MTG under natural sunlight (**B**).

Table 6. Scion and rootstock stem diameters, scion dry biomass, leaf area, internode length, and chlorophyll index of 'Washington' Navel on Carrizo and Rubidoux 14 weeks after budding.

Factor	Scion stem diameter (mm)	Rootstock stem diameter (mm)	Scion dry biomass (g)	Scion leaf area (cm^2)	Internode length (mm)	Chlorophyll index
MTG						
Light treatment						
NSL	3.7 b	7.0 b	4.6 b	495 b	16.4	69.7 b
DLE + P	4.4 a	7.9 a	7.7 a	649 a	15.8	74.8 a
DLE	4.3 a	7.8 a	7.7 a	647 a	15.7	75.8 a
NI + P	3.6 b	6.8 b	4.4 b	456 b	16.3	68.3 b
NI	3.7 b	6.9 b	4.7 b	481 b	16.0	69.9 b
P-value	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.632*	*<0.001*
Rootstock						
Carrizo	4.5 a	7.9 a	8.0 a	723 a	17.3 a	71.6
Rubidoux	3.3 b	6.6 b	3.6 b	368 b	14.8 b	71.9
P-value	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.537*

From:
Horticulturae **2024**, *10, 897*

Conclusions – year 1

- Day-length extension to 16 hours increased the scion growth, but only when supplemental heating was provided.
- Night interruption did not affect scion budbreak or growth under any of the tested conditions.
- Preconditioning enhanced scion growth slightly in some instances.
- Growth effects from light were stronger when the Navel scion was grafted on Carrizo compared to Rubidoux.

Year 2 Objective:

Evaluate budbreak and growth effects from light spectral quality and intensity in the winter citrus nursery.

Year 2 of the study used a complex experimental design to evaluate different light spectra (wavelengths) and light intensity.

Factors and factor levels (Table 1).

Table 1. The four LED light factors and their ranges used to construct the experimental design.

Factors	LED (peak wavelength, nm)	Range (watts)
1	Red (660)	0 – 1,000
2	Blue (450)	0 – 1,000
3	White (446, 534, 625)	0 – 1,000
4	Far-red (735)	0 – 1,000

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Responses measured (Table 2).

Table 2. Eight responses measured and their units.

#	Responses	Units
1	Budbreak	%
2	Scion shoot growth	mm
3	Scion diameter	mm
4	Rootstock diameter	mm
5	Internode length	mm
6	Leaf area	cm^2
7	Scion biomass	kg
8	Chlorophyll index	greenness

ANOVA Summary (Part 1)

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ANOVAs for the effect of 4 LED lights on 8 measures on 2 rootstocks (Table 4). Light effects were adjusted for temperature variation.

Table 4. ANOVA model terms, p-values (Prob. > F), lack-of-fit, R^2, and adequate precision statistics for the effect of light on % budbreak, shoot growth, and scion and rootstock diameters, internode length, leaf area, scion biomass, and chlorophyll index. Terms with the greatest effects are highlighted. Red – negative effect, Green – positive effect, Yellow – large interaction or quadratic effect.

	Budbreak (%)		Scion shoot growth (mm)		Scion diameter (mm)		Rootstock diameter (mm)	
Source	**Carrizo**	**Rich 16-6**	**Carrizo**	**Rich 16-6**	**Carrizo**	**Rich 16-6**	**Carrizo**	**Rich 16-6**
Model	9.76E-5	0.0061	1.45E-6	0.0361	0.0011	0.0005	1.43E-13	0.0039
A – Red	0.0028	0.8288	0.5503	0.4760	0.7576	0.0019	0.5208	0.0002
B – Blue	0.0278	0.0144	0.9720	0.4135	-	0.6495	0.0183	0.5094
C – White	0.0370	0.3154	0.0040	-	0.9699	-	0.2875	0.0375
D – Far-red	0.8689	0.1552	0.1671	0.9532	0.9920	-	0.0002	0.6648
AB – Red x Blue	-	-	0.0577	-	-	0.0635	-	-
AC – Red x White	-	-	0.0198	-	0.0064	-	0.0160	-
AD – Red x Far-red	0.0021	0.0597	-	0.1214	0.0490	-	-	-
BC – Blue x White	-	-	0.0023	-	-	-	0.1250	-
BD – Blue x Far-red	-	-	-	-	-	-	-	-
CD – White x Far-red	-	-	0.0461	-	-	-	-	0.0777
A^2 – Red^2	-	-	0.0021	-	-	-	4.07E-5	-
B^2 – $Blue^2$	0.0244	-	-	0.0062	-	0.0275	-	-
C^2 – $White^2$	-	-	-	-	-	-	0.0225	-
D^2 – $Far\text{-}red^2$	-	-	0.0098	-	-	-	-	-
Lack of Fit	0.0124	0.0212	0.0028	0.6621	0.0036	0.9749	0.1513	0.3767
R^2	0.2224	0.1638	0.3707	0.1314	0.1980	0.1780	0.5452	0.1865
R^2 adj	0.1796	0.1096	0.2974	0.0729	0.1456	0.1457	0.4971	0.1290
R^2 pred	0.1154	0.0388	0.1993	-0.0117	0.0866	0.0969	0.4354	0.0285
Adequate precision	8.5	5.9	8.4	5.9	7.08	6.4	13.8	6.4
Transformation	no	$\lambda = 0.76$	no	no	no	no	no	no
Model type[e]	reduced quadratic	reduced 2FI	reduced quadratic	reduced quadratic	reduced 2FI	reduced quadratic	reduced quadratic	reduced 2FI

Percentage of budbreak

Source	*p*-value		Effect
Model	< 0.0001	significant	
A-Red	0.0027	**	-5.10
B-Blue	0.0271	*	+4.06
C-White	0.0361	*	+3.57
D-Far-red	0.8681	NS	+0.2745
AD	0.0020	**	+5.42
B^2	0.0237	*	+8.00
Lack of Fit	0.3386	NS	

Conclusions – year 2

Different light spectra and intensity significantly affect budbreak and bud growth on citrus young plants.

Budbreak:

- **Blue** and **white** spectra combined increases budbreak
- **Red** and **far-red** spectra combined reduces budbreak

Shoot growth:

- **Blue**, **red** and **white** spectra combined increases shoot growth

Project Objectives – Year 3

Objective 3. Evaluate influence of spectral quality and intensity on budbreak and growth effects.

Objective 4. Evaluate influence of BA application on budbreak and growth effects.

Effects on budbreak

Table 1. Percentage of vegetative budbreak at 6, 9, and 12 weeks after budding (wab) and bud survival at 12 wab of 'Washington' navel orange nursery plants grafted on Carrizo and Rubidoux rootstocks cultivated under supplemental LED lighting treatments and 6-benzyladenine (6-BA).

Source of variance	Budbreak (%)			Bud survival (%)
	6 wab	9 wab	12 wab	12 wab
Light treatment[1]				
NoSL	54.5 b[3]	62.2 b	64.8 b	64.1 b
FSL	70.5 a	78.5 a	82.3 a	80.2 a
BWSL	62.8 ab	72.7 ab	75.6 ab	73.4 ab
BWSL+FSL	69.1 a	76.7 a	80.9 a	77.4 a
Rootstock				
Carrizo	75.9 a	78.9 a	82.1 a	83.9 a
Rubidoux	52.6 b	60.0 b	62.9 b	63.7 b
PGR[2]				
No PGR	53.1 b	63.4 b	68.8 b	70.7 b
6-BA	75.3 a	75.5 a	76.2 a	76.9 a
F-value (df)				
Light (3)	5.1 **	6.6 **	5.8 **	5.1 **
Rootstock (1)	87.4 ***	57.3 ***	59.4 ***	70.4 ***
PGR (1)	79.8 ***	23.6 ***	8.8 **	6.8 *

Effects on scion growth

Table 3. Horticultural assessments of 'Washington' navel orange nursery plants grafted on Carrizo and Rubidoux rootstocks cultivated under different supplemental LED lighting treatments and 6-benzyladenine (6-BA) 12 weeks after budding (wab) in a greenhouse.

Source of variance	Rootstock stem diameter (mm)	Scion stem diameter (mm)	Total scion leaf area (cm^2)	Scion dry biomass (g)
Light treatment[1]				
NoSL	6.13 c	3.23 c	244.5 c	2.47 d
FSL	6.72 a	3.60 a	455.6 a	5.17 a
BWSL	6.49 b	3.38 b	333.7 b	3.45 c
BWSL+FSL	6.51 b	3.36 b	370.7 b	3.98 b
Rootstock				
Carrizo	7.44 a	4.07 a	506.9 a	5.57 a
Rubidoux	5.48 b	2.71 b	195.3 b	1.97 b
PGR[2]				
No PGR	6.42 b	3.31 b	327.2 b	3.47 b
6-BA	6.62 a	3.48 a	375.0 a	4.06 a

Conclusions – All 3 years

- Day-length extension to 16 hours increased the scion growth and budbreak, but only when supplemental heating was provided.
- Night interruption did not affect scion budbreak or growth in our study.
- Light-preconditioning enhanced scion growth slightly in some instances.
- Combined blue and white light increased budbreak; Combined red and far-red light decreased budbreak. Broad spectrum light was most effective at increasing shoot growth.
- Higher intensity light had more positive effects on budbreak and growth than lower intensity light.
- Growth effects from light were stronger when the scion was grafted on Carrizo compared to Rubidoux.
- Application of BA to the grafted bud enhanced budbreak.